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**An acoustic analysis and cross-linguistic
study of the phonemic inventory of Nez Perce**


by

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ABSTRACT

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This dissertation is an acoustic description of the phonemic inventory of Nez Perce [nez], a Penutian language spoken in the Pacific Northwest of the United States. Acoustic work has been conducted on the consonants of Nez Perce, but no acoustic work had been conducted on the vowels or the vowel harmony system. This work begins with an overview of the dissertation, the Nez Perce language situation, previous research on Nez Perce, and general methodology. Following the introduction chapter, I present chapters on the ejectives and plain obstruents, the plain and glottalized sonorants, the vowels, vowel harmony, and the conclusion.

Nez Perce has both plain and ejective stop series, plain and ejective affricate series, and a plain fricative series. I examine the acoustic correlates of these segments comparing them to previous research, other languages and current phonetic theory. The ejectives are described by measuring f_0 , intensity, jitter, burst amplitude and voice onset time. I discuss the fricatives in terms of the spectra, duration, formant transitions, and the four moments.

The timing and realization of glottalization on glottalized and plain sonorants is investigated. All segments are measured for duration and are visually and aurally inspected for variation in the glottalization, which is realized using pitch, laryngealization, several glottal stops, a single glottal stop, or a combination of these features. The glottalization is nearly always realized on the sonorant rather than before or after the segment.

Vowels are discussed with respect to previous phonological descriptions and plotted. The Nez Perce vowel inventory is /i, æ, a, o, u/ rather than the canonical five-vowel system of /i, e, a, o, u/, which has led to the description of the inventory as having a “gap” and as not maximally contrastive. I suggest in Chapter 4 that if Nez Perce vowels are considered using a shifted axis, with the high front vowel as the tip of the triangle rather than the low vowel, then the vowels are maximally contrastive.

The non-canonical vowel inventory leads to two seeming unrelated vowel harmony sets: dominant, /i, æ, u/, and recessive, /i, a, o/. The proposed shifted axis view of the vowel system becomes important for reanalyzing the vowel harmony to reconcile these two unusual sets. Previous analyses have described Nez Perce vowel harmony as based on advanced tongue root (ATR). I investigated Nez Perce vowels for acoustic correlates of ATR; however, the results provide evidence both showing and not showing ATR correlates. I propose an alternate analysis for the vowel harmony system based on the principle of maximal contrast, evidenced by the shifted axis model, and the hyperspace effect.

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List of abbreviations

A1-A2	First amplitude minus second amplitude
ATRB	Attributive suffix
B1	First bandwidth
B2	Second bandwidth
DOM	Dominant
f0	Fundamental frequency
F1	First formant
F2	Second formant
F3	Third formant
INC	Incompletive Aspect
POA	Place of articulation
REC	Recessive
REP	Recent Past
SUV	Stressed and unstressed vowels
SV	Stressed vowels
VOT	Voice onset time
*	Indicates significance between 0.05 and 0.01
**	Indicates significance between 0.01 and 0.001
***	Indicates significance greater than 0.001

Chapter 1

Introduction

1.1. Introduction

This dissertation provides a phonetic description of Nez Perce, an American Indigenous language, based on recordings of five native speakers. Nez Perce phonetics and phonology has received little attention outside of the unusual vowel harmony process, which has been of great interest to phonologists. This phonological work did not include any acoustic phonetic work. Although other phonetic descriptions included in grammars of the language have been conducted by ear, this dissertation will be the first acoustic phonetic work of the vowels and vowel system (Aoki 1965; Rude 1985; Crook 1999).

While earlier phonetic descriptions were conducted before acoustic documentation became readily accessible, they have been fairly accurate, and serve as the foundations for this dissertation. In addition to these studies, there are four

papers on Nez Perce acoustic phonetics. One paper is on the glottalized sonorants (Um 2001), where Nez Perce is one of seventeen language included in the study. The other three studies examine the ejectives and stops: Aoki 1970 provided durational measurements for Nez Perce ejectives, and Maddieson (1984) looked to see if there was place dependent voice onset time (VOT) for ejectives. In addition, I (Nelson 2010) conducted an in-depth acoustic study of the ejectives.

This dissertation focuses on the phonetic aspects of the language. Outside of the introduction and the conclusion I do not comment of the status of the language. While there is the potential for language change to have occurred with the increased use of English over the years, it is not the purpose of the dissertation to comment on these changes. The purpose of this dissertation is to describe the phonetic structures of Nez Perce as spoken by the five speakers used in this study.

Although I only discuss the language status in the introduction and conclusion, one of the purposes of this study is to assist in the preservation of the language and to provide a description of the phonetics to aid in language instruction. Thus, the purpose of this study is threefold: (1) to document and analyze the sound system of the Nez Perce language, providing a database for linguistic comparison and description; (2) to aid in the preservation of the language; and (3) to provide a record of the sound system for use by the Nez Perce in the instruction of their language.

1.2. Structure of the dissertation

Chapter 1 of the dissertation provides the goals of the dissertation, an overview of the language situation, and an outline of the dissertation as a whole. The following four chapters discuss various phonetic aspects of the language and compare them to other languages, starting with ejectives and plain obstruents in Chapter 2, including data from a previous study I conducted on the ejectives (Nelson 2010). Chapter 3 covers plain and glottalized sonorants, which are rare sounds in the world's languages. Conducting a detailed phonetic description of these segments will provide important data for furthering linguists' understanding of them. Chapter 4 discusses the vowels in Nez Perce, including spectrograms and vowel plots. In this chapter, I discuss the principle of maximal contrast (Liljencrants & Lindblom 1972) and the hyperspace effect (Johnson, Flemming and Write 1993) in relation to Nez Perce. I propose that Nez Perce vowels are maximally dispersed despite the "gap" in the inventory (the presence of a low front vowel rather than a mid front vowel). Because of the extensive prior research on the topic of vowel harmony in Nez Perce, I present this in Chapter 5. Previous research on Nez Perce vowel harmony is reviewed and the vowel harmony system is phonetically examined for acoustic correlates of advance tongue root (the most common analysis for Nez Perce vowel harmony). I also propose an alternate analysis for the vowel harmony based on the principle of maximal contrast and the hyperspace effect.

1.3. Nez Perce language situation

The Nez Perce¹ language, a Penutian language of the Pacific Northwest, is a member of the Sahaptian sub-branch of the Penutian family and is most closely related to Sahaptin (Dryer 1995). The Nez Perce call themselves *niimípuu*, literally meaning ‘Nez Perce people’; their word for the language is *niimiipuutímt* meaning ‘Nez Perce language’.



Figure 1 Penutian language family (Dryer 1995 from multitree)

There are currently about twenty² speakers of Nez Perce all over the age of 65 (A. Sobotta,³ p.c., August 30, 2010). Although children are exposed to Nez Perce

¹ Nez Perce is pronounced [nez pəʃ] rather than [nez pi:ʃ].

² The number of speakers varies depending on how one counts native speakers.

³ Angel Sobotta is a language coordinator and administrator for the Nez Perce language program.

at school, it is the students' choice whether or not to learn the language. In addition, there are some very good heritage speakers. There has been discussion of a Nez Perce language immersion school on the reservation in Lapwai, however funding needs to be secured.

Nez Perce is spoken on four reservations: the Nez Perce Reservation in western Idaho, the Umatilla Reservation in northeastern Oregon, the Yakama Reservation in south-central Washington, and the Colville Reservation in eastern Washington, all of which can be seen in Figure 2.

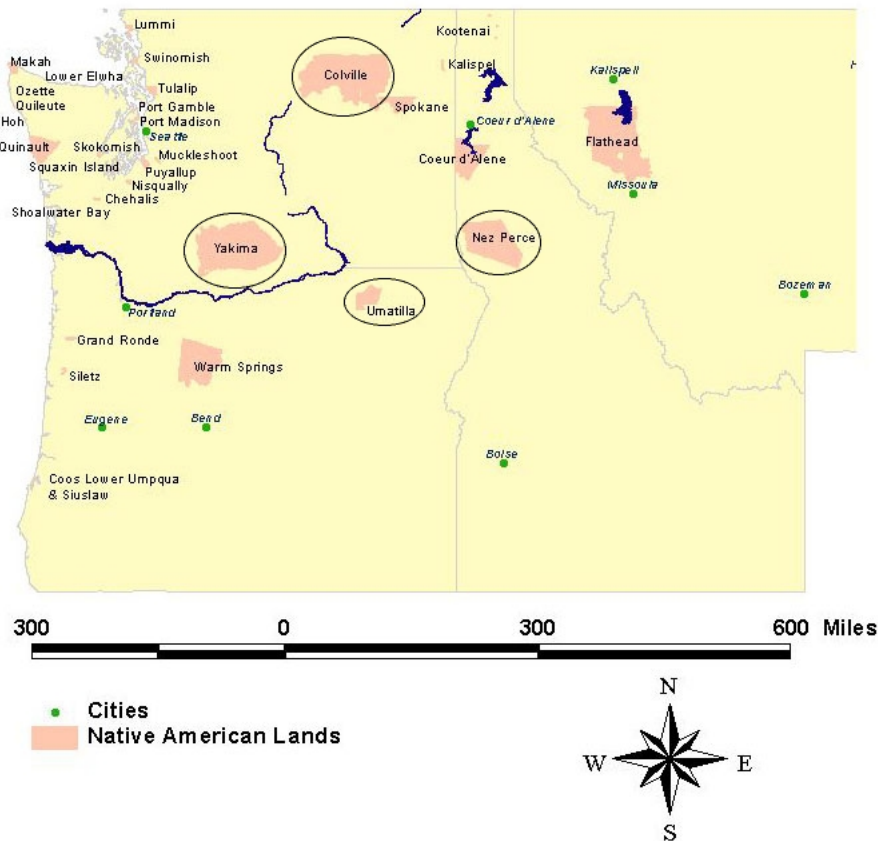


Figure 2 Reservations of the Pacific Northwest (UW digital libraries: Indian Reservations of Northwest Coast and Plateau Cultural Groups, ND).

The Yakama Nation, Colville, and Umatilla Reservations are home mainly to Sahaptin speakers, but there are also some Nez Perce speakers living on these reservations. The majority of the Nez Perce speakers, however, both native and second language, reside on the Nez Perce Reservation (in western Idaho).

There is an active language center on the Nez Perce Reservation funded by grants. At the language center, visiting linguists can meet with elders and research various aspects of the language. Staff members at the language center work on developing new ways to preserve their language as well as to teach the language to the Nez Perce community.

In 2009 the Nez Perce Language Program conducted a study, “Nez Perce Language Assessment Report” (Cash Cash 2009), to investigate the use and transmission of the language to younger generations as well as the maintenance of the language in older speakers. Specifically, the use of Nez Perce in the home, the contexts in which it is used, fluency of native speakers and language learners, as well as the community’s attitudes about language education and preservation were investigated. The study found that most Nez Perce use the language when a grandparent is around and then the extent of the use is dependent upon the knowledge of the other members of the family. Many Nez Perce expressed a desire to learn the language, although they encountered many hindrances trying to learn it. These included difficulty finding the time to study and travel to classes, difficulty finding other learners to speak with, and few healthy fluent speakers to teach learners (Cash Cash 2009: 8). The study recommends developing curriculums based in the community and families to promote intergenerational language learning, certifying more Nez Perce language teachers and promoting language program support to more activities on the reservation, local school districts and surrounding universities (Cash Cash 2009: 14).

1.4. Theoretical issues addressed

Research by Aoki (1965) and Crook (1999) established the Nez Perce phonemic inventory. The inventory has 26 consonants, five monophthongal vowels and seven diphthongs all with phonemic length. This is presented in Figure 3, Figure 4, and Figure 5.

		Labial	Dental	Alveolar	Palatal	Velar	Uvular	Glottal
Plain								
	Stops	p	t			k	q	ʔ
	Affricates			ts				
	Fricatives		ʈ	s		x	χ	h
	Nasals	m	n					
	Glides	w			j			
	Liquids		l					
Ejectives								
	Stops	p'	t'			k'	q'	
	Affricates			ts'				
Glottalized								
	Nasals	m̥	n̥					
	Glides	w̥			ṵ			
	Liquids		l̥					

Figure 3 Nez Perce consonant inventory (adapted from Crook 1999: 13).

As illustrated in Figure 3, Nez Perce has a set of both ejective and plain obstruents, comprised of stops and affricates. In addition there is a set of glottalized and plain sonorants. Only the fricatives do not have ejective phoneme counterparts. [w] and [w̥] are placed under labial even though they are labio-velar.⁴ The glottalized palatal is marked above the character to facilitate reading.

The vowel inventory has five monophthongal vowels (Figure 4) and seven diphthongal vowels (Figure 5) all with phonemic length. These vowels also undergo

⁴ Crook listed the palatal glides are velars. I have listed them as palatal.

vowel harmony (see Chapter 5). /æ/ is written as <e> and long vowels, /i:/ for example, are written as <ii> in the Nez Perce Practical Orthography.

	<u>Short</u>			<u>Long</u>		
	<u>Front</u>	<u>Central</u>	<u>Back</u>	<u>Front</u>	<u>Central</u>	<u>Back</u>
High	i		u	i:		u:
Mid			o			o:
Low	æ	a		æ:	a:	

Figure 4 Nez Perce monophthongs (Crook 1999: 21).

<u>Diphthongs</u>						
	<u>Short</u>			<u>Long</u>		
	<u>Front</u>	<u>Central</u>	<u>Back</u>	<u>Front</u>	<u>Central</u>	<u>Back</u>
	iw	aw	uy	i:w	a:w	u:y
	æw	ay	oy	æ:w	a:y	o:y
	æy			æ:y		

Figure 5 Nez Perce diphthongs listed by the frontness and backness of the nucleus.

In Chapter 4, the unusual five-vowel inventory will be discussed in relation to the principle of maximal contrast (Liljencrants & Lindblom 1972) and the hyperspace effect (Johnson, Flemming, and Wright 1993).

1.5. General methodology

Each chapter contains a comprehensive methodology section. The purpose of this is to facilitate reading and to allow each chapter to be read independently.

Additionally, the data for each chapter were analyzed independent of the other chapters and were recorded during separate trips. The research was conducted over portions of three summers (2009, 2010, 2011) in Lapwai, Idaho. The summers when the data were collected are identified in each chapter as well. During these trips, I met regularly with native speakers to develop wordlists. As will be discussed in the following chapters all measurements and data analysis were conducted with Praat (Boersma & Weenink 2010) scripts and were hand checked.

1.5.1. Speakers

Five speakers were used in the study, three women and two men. All have worked with linguists fairly regularly. FS1 (Female Speaker 1), age 73, works regularly at the language center, was a Head Start teacher and taught Nez Perce. FS2 (Female Speaker 2), age 75, also works regularly at the language center. FS3, age 68, works at the language center less often than FS1 and FS2 and is an administrator in one of the tribal offices. MS1 and MS2 are both in their 80's. MS1 was the primary consultant for a grammar. MS2 is a highly respected and sought after orator.

All speakers spoke English once attending school but spoke Nez Perce at home until they were older. The extent of Nez Perce use varied later in life as some of the speakers moved away for a period of time but later returned. All of the speakers' fluency levels were rated as "high" or "high-fluent" by the tribe.

All speakers are referred to by their gender and a number. The female speakers, for example, are FS1, FS2, and FS3 (female speaker 1, female speaker 2, and female speaker 3). Similarly the male speakers are referred to as MS1 and MS2 (male speaker 1 and male speaker 2).

Chapter 2

Plain obstruents and ejectives

This chapter investigates the various aspects of plain obstruents (stops, affricates and fricatives) and ejectives (stop ejectives and the affricate ejective). I describe the plain obstruents and ejectives using voice onset time (VOT), burst amplitude, closure duration, and rise time (change in intensity). The ejectives, plain stops, and plain affricate sections are based in part on a previous study of Nez Perce ejectives (Nelson 2010). The fricatives are discussed using spectra, the four moments, duration, and intensity.

2.1. Background

Nez Perce has two stops series: a plain series and an ejective series. The plain series, /p t k q ʔ/, has five places of articulation: bilabial, alveolar, velar, uvular,

and glottal, while the ejective series, /p' t' k' q'/, has four places of articulation: bilabial, alveolar, velar, and uvular.⁵ These segments can be seen in Figure 6. This is not a complete consonant inventory for Nez Perce. I have only included the segments that will be discussed in this chapter. For the complete consonant inventory, see Section 1.4.

	Labial	Dental	Alveolar	Palatal	Velar	Uvular	Glottal
Plain							
Stops	p	t			k	q	ʔ
Affricates			ts				
Fricatives			s		x	χ	h
Lateral Fricative			ɬ				
Ejectives							
Stops	p'	t'			k'	q'	
Affricates			ts'				

Figure 6 Plain obstruents and ejectives inventory (adapted from Crook 1999: 13).

Cross-linguistically it is common to have two series of stops (Maddieson 1984: 39). Maddieson finds that 51.1% of the 317 languages surveyed in UPSID⁶ have two stop series like Nez Perce and 16.4% of these languages have a voiceless⁷ ejective stop series (27). He finds that cross-linguistically languages commonly

⁵ There cannot be an ejective glottal stop because ejectives require a closure at the glottis and a location in mouth. While there is a closure in the mouth and at the glottis, the glottis raises compressing the air. When the place of articulation in the mouth is released the compressed air is released and the glottis lowers.

⁶ Maddieson uses UPSID, the UCLA Phonological Segment Inventory Database, which is a collection of 317 languages in his 1984 book, *Patterns of Sounds*, to describe generalizations about consonant inventories of the world's languages, including Nez Perce.

⁷ Voiceless as opposed to prevoiced, because ejectives cannot be voiced.

(53.9%) have stops in three different places of articulation (1984: 39), and 11% of the languages studied, including Nez Perce, have a stop series with five places of articulation (31).

In addition to the stop series, there are five fricatives in Nez Perce, /s ʃ x ɣ h/, all voiceless: an alveolar, a lateral alveolar, velar, uvular and glottal. There is one strident fricative, /s/, and four non-strident fricatives, /ʃ x ɣ h/. While both the strident and non-strident fricatives require fast moving air through a constricted area, stridents require an obstruction that causes the air stream to encounter a hard object, such as the teeth (Ladefoged 2005: 167). Strident fricatives are more common cross-linguistically because they create greater energy and are therefore easier to distinguish (167). Despite being more common cross-linguistically, there are phonemically fewer possible stridents than non-stridents. Even though stridents are easier to distinguish, Nez Perce has four non-stridents and only one strident. The language utilizes fricatives that are at the POAs of the stops rather than using the more distinct strident fricatives and thus introducing new POAs. Speakers are most likely already attuned to the POAs seen in the stops, which allows for ease of perception in the non-strident fricatives.

Further adding to the Nez Perce inventory are the affricates. Maddieson finds in his study of UPSID that “the most common non-lateral and non-ejective affricates are palato-alveolar in place and strident in nature. The next most frequent [affricates] are dental or alveolar [strident] affricates” (1984: 38). Nez Perce follows

the second generalization with two voiceless alveolar affricates, one plain and one ejective.

In his generalizations on affricates and stops, Maddieson finds that languages tend to have stops and/or affricates at four different places of articulation (1984: 40). Nez Perce has affricates and/or stops (as well as fricatives) in six different places of articulation: bilabial (stop), dental (stop), alveolar (affricate and two fricatives), velar (stop and fricative), uvular (stop and fricative), and glottal (stop and fricative).

The current phonological inventory based on the work by Aoki (1965), Rude (1985), and Crook (1999) accurately represents the Nez Perce phoneme inventory. The purpose of this chapter is to provide supporting phonetic data for their analysis and for future phonetic and phonological typological work.

2.2. Data and methodology

Data for this chapter were collected during the summers of 2009, 2010, and 2011 in Lewiston and Lapwai, Idaho. The word lists used in this study were compiled using Aoki's *Nez Perce Dictionary* (1994), Crook's dissertation (1999), language learning materials (NPLP 2002a, 2002b, 2003, 2004, 2007, 2010a, 2010b, 2010c, 2010d, 2010e, ND; NPLP & Crook ND), and native speakers. Words were chosen from the above texts, examined by native speakers and archaic words were eliminated. Additionally, ungrammatical constructions were corrected or

eliminated. Words that were determined suitable were compiled into a final word list.

Native speakers were recorded in quiet rooms with a Zoom H4n recorder and an AKG C555L head-mounted microphone with an AKG MPA VL adapter. Speakers recorded the words two or three times⁸ in either isolation or in a carrier phrase.⁹

The number of tokens varies for each speaker because tokens were discarded due to background noise, devoiced vowels (for the target vowels), or if upon analysis one of the aspects of study was not calculable (for example, f0, formants, intensity, or outliers). In addition the word list for the ejective and plain obstruent section is different from the word list for the fricatives section.

The results from my previous study on ejectives (Nelson 2010) showed that the word-medial position is a stronger position in Nez Perce. Thus the data in this chapter is based on word-medial tokens, whereas the data from my 2010 study included both word-initial tokens and word-medial tokens.

I include the plain and ejective affricates together with the plain stops and ejective stops in my analysis. The fricated portion of the affricate is often longer than the VOT for stops, however since I am including the affricate in the analysis for

⁸ Though carrier phrases are intended to elicit more natural speech I was told after using a carrier phrase, “Héenek'e ____ híce” (translation: ‘Say ____ again.’), that carrier phrases were in fact not very natural for these speakers, as the words were not being used in a conversation or story.

⁹ Not all speakers had enough time to repeat the words three times, so to ensure I collected each word on the word list some speakers only repeated the words twice.

both the ejectives and the plain obstruents, both VOT measurements will be equally affected by the inclusion of the affricates.

The token count for the fricatives for FS1 (Female Speaker 1) is 82 tokens, FS2 is 103 tokens, FS3 is 34 tokens, MS1 (Male Speaker 1) is 78 tokens, and MS2 is 107 tokens. For the plain obstruents and ejectives, MS1 (Male Speaker 1) has 326 tokens and MS2 has 199 tokens. Data from a previous study (Nelson 2010) will be used for FS1, FS2, and FS3. These token counts include words that were repeated three times, so these repetitions were averaged together for each speaker.

The plain obstruents and ejectives section utilizes a repeated measures ANOVA for the statistical analysis because intensity, jitter¹⁰, and F0, were measured twice in the vowel following the target ejective, plain obstruent, and plain affricate. The interdependence of these measurements required a repeated measures setup. The remaining variables—duration of the whole consonant, voice onset time (VOT), closure duration, burst amplitude, and vowel duration—were analyzed using a standard ANOVA. The independent variables are the place of articulation (POA), the vowel following the segment, vowel length, and whether the segment is plain or ejective. The dependent variables are duration of the whole consonant, VOT, closure duration, burst amplitude, vowel duration, fundamental frequency (f0) at 30ms and midway into the following vowel, intensity at 30ms and midway into the

¹⁰ The average duration between glottal pulses.

following vowel (rise time), and jitter at 30ms and midway into the following vowel.¹¹

The fricatives were studied using descriptive statistics. They were studied based on the place of articulation of the fricative. The duration of the fricative, center of gravity (first moment), standard deviation (second moment), skew (third moment), kurtosis (fourth moment), and maximum intensity were all studied for each fricative.

2.3. Results

The following section provides results for the plain obstruents and ejectives, followed by the glottal stop, and concludes with the fricatives. I am presenting the results for the ejectives with the plain stops and plain affricate. I will highlight the results for both in my discussion of the data.

2.3.1. Plain stops, the plain affricate and ejectives

In Nelson (2010), I presented a new description for ejectives based on the work of Lindau (1984), Kingston (1985, 2005) and Wright et al. (2002). Kingston studied the many features of ejectives: VOT, burst amplitude, f0, voice quality, and rise time (intensity). The different results of VOT, burst amplitude, f0, voice quality,

¹¹ If the duration of the vowel was around 60ms then these two measurements would have been very close. There are no vowels in the data for the men that are this short, though there are a few in the data for the women that are so short. Not enough to affect the data.

and rise time indicate whether the ejective is stiff or slack. These aspects are presented in Table 1 with indicators for stiff and slack ejectives; for example, if the voice quality is creaky on the vowel following the ejective, that points to a slack ejective. I also indicate which researcher and paper on ejectives discussed the feature.

Table 1 Stiff and slack features of ejectives. Based on Wright et al. (2002).

	Stiff	Slack	Sources
VOT	Long	Short	Lindau (1984), Kingston (2005)
Burst amplitude	Intense	Normal	Kingston (1985, 2005)
f0	High	Low	Kingston (1985, 2005)
Voice quality	Modal or Tense	Creaky	Lindau (1984), Kingston (2005)
Rise time (intensity)	Fast	Slow	Lindau (1984), Kingston (2005)

Where Kingston summarizes all of these individual features and describes ejectives, wholly, as stiff or slack only, I (Nelson 2010) proposed keeping all of these individual features separate. I suggested this because many researchers (Wright et al. (2002), Witsuwit'en; Kingston (1985), Tigrinya; Lindau (1984), Navajo and Hausa; Ingram & Rigsby (1987), Giksan; Nelson (2010), Nez Perce), have found intra- and inter-speaker variation and have mentioned that collapsing all of the

categories can be problematic. Not collapsing the individual features to summarize the whole ejective will allow for more cross-language comparison and, in general, a better understanding of ejectives.

The features presented in Table 1 and discussed above are described for the male speakers, MS1 and MS2, in detail below. Following this description the results are summarized in a similar table that includes the data from three female speakers from Nelson (2010).

MS1 and MS2 do not show the significant results for VOT that I saw in the 2010 study (see Table 2). MS1 shows a VOT that is shorter than the plain obstruents, as seen in Figure 7. The difference between the VOT for the ejective (63.93ms) and the plain obstruents (75.74ms) is not significant [$F(1, 43)=0.126$, $p=0.737$]. The short VOT and lack of significance points towards a VOT representative of a slack ejective.

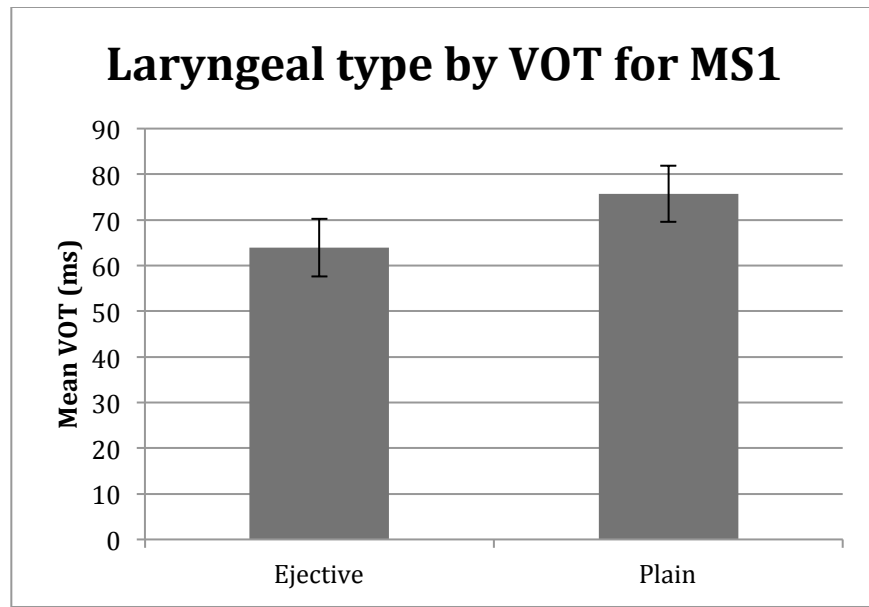


Figure 7 Mean VOT for speaker MS1 by laryngeal type. Error bars show standard error.

MS2, Figure 8, shows a significantly longer VOT for the ejectives (47.76ms) than for the plain obstruents (37.02ms) pointing toward a stiff ejective [$F(1, 30)=10.21, p=0.033$].

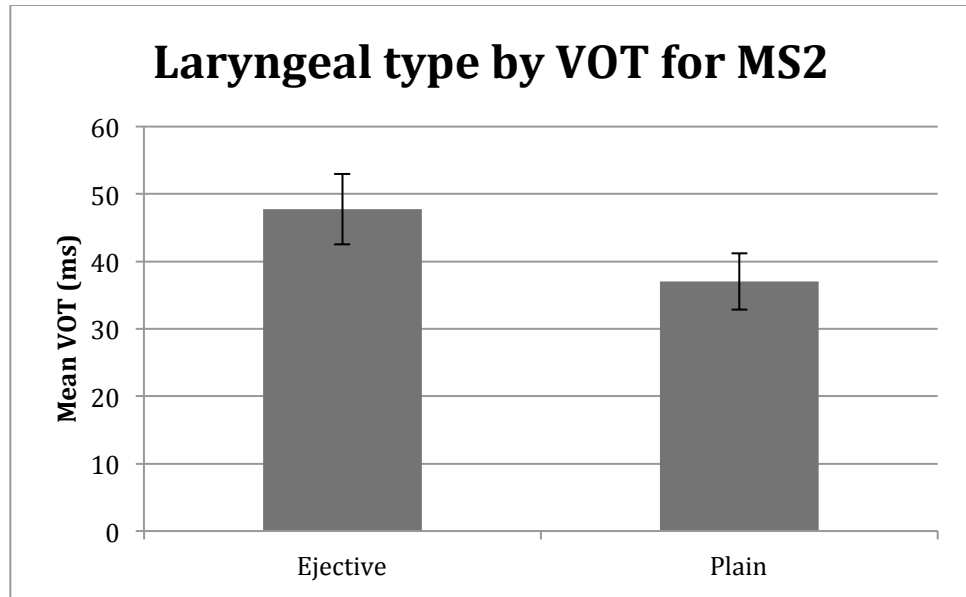


Figure 8 Mean VOT for MS2 by laryngeal type. Error bars show standard error.

Both male speakers also show a burst amplitude that points toward a slack ejective. MS1, Figure 9, shows a burst amplitude that is slightly stronger for the ejective (0.016Pa2s) than for the plain obstruents (0.014Pa2s), however this difference is not significant [$F(1, 43)=0.47, p=0.52$]. The lack of significance and the slight difference between the ejective and plain obstruent burst amplitude (0.002 pascals) support a slack analysis for burst amplitude for MS1.

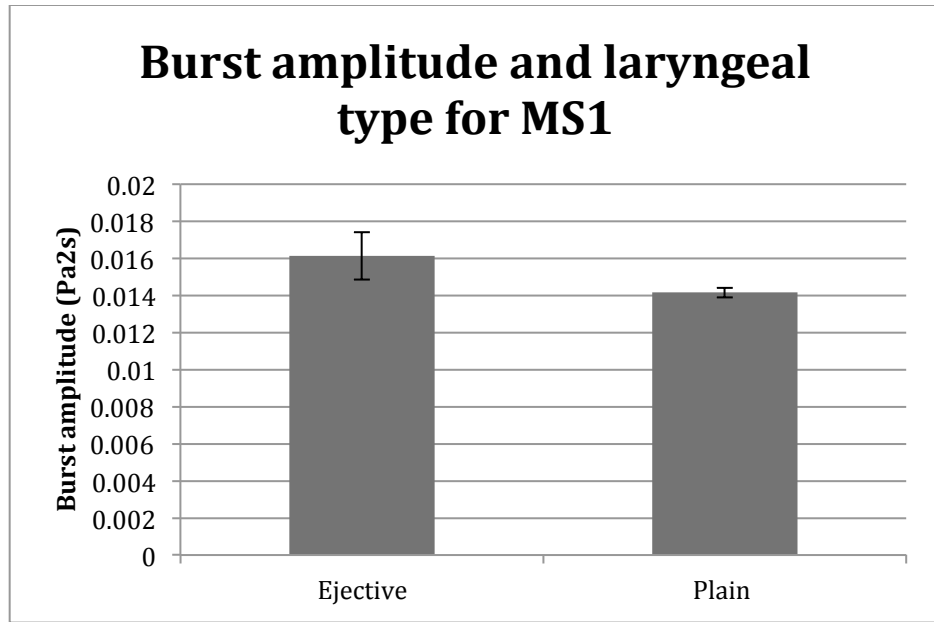


Figure 9 Mean burst amplitude for MS1 in pascals. Error bars show standard error.

MS2, Figure 10, also shows characteristics of a slack burst amplitude. The burst amplitude for the ejectives (0.0125Pa2s) and the plain obstruents (0.0128Pa2s) are the same with only a 0.0002Pa2s difference. As would be expected, this difference, or lack thereof, is not significant, suggesting a slack ejective burst amplitude [$F(1, 30)=0.284, p=0.623$].

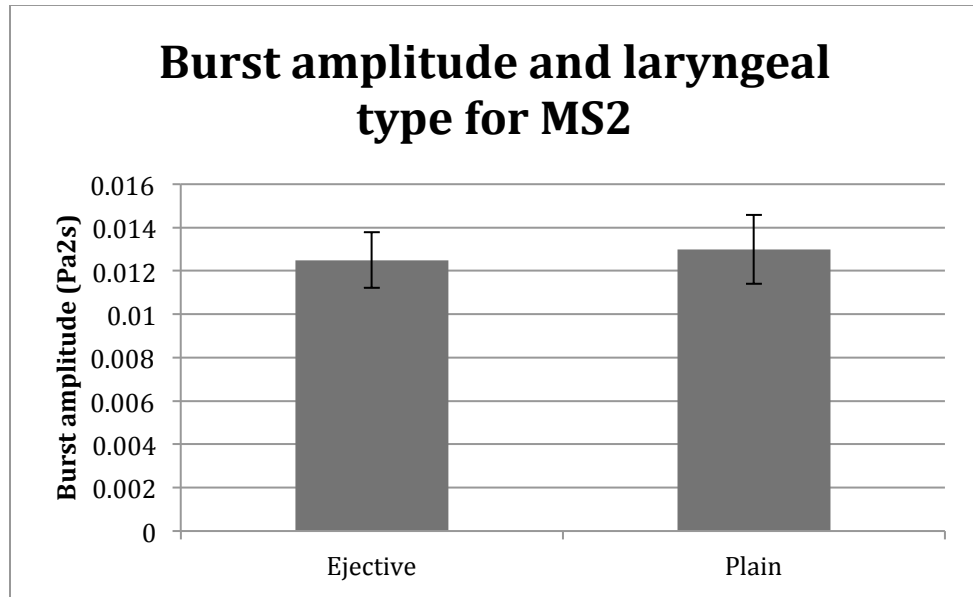


Figure 10 Mean burst amplitude for MS2 shown in pascals. Error bars show standard error.

MS1, Figure 11, shows a significant difference for the within-subjects variable in the f_0 and the laryngeal type [$F(1, 43)=39.50, p=0.001$]. He also shows a significant difference in the between subjects variable for laryngeal type [$F(1, 43)=12.44, p=0.017$], showing that there is a difference between the f_0 for the ejectives and for the plain obstruents independent of the measurement location (at 30 ms into the vowel or at the vowel midpoint). The mean f_0 at 30ms for the ejectives is 164.05Hz and at the midpoint is 141.57Hz. The mean f_0 at 30ms for the plain obstruents is 149.63Hz and at the midpoint is 135.60Hz.

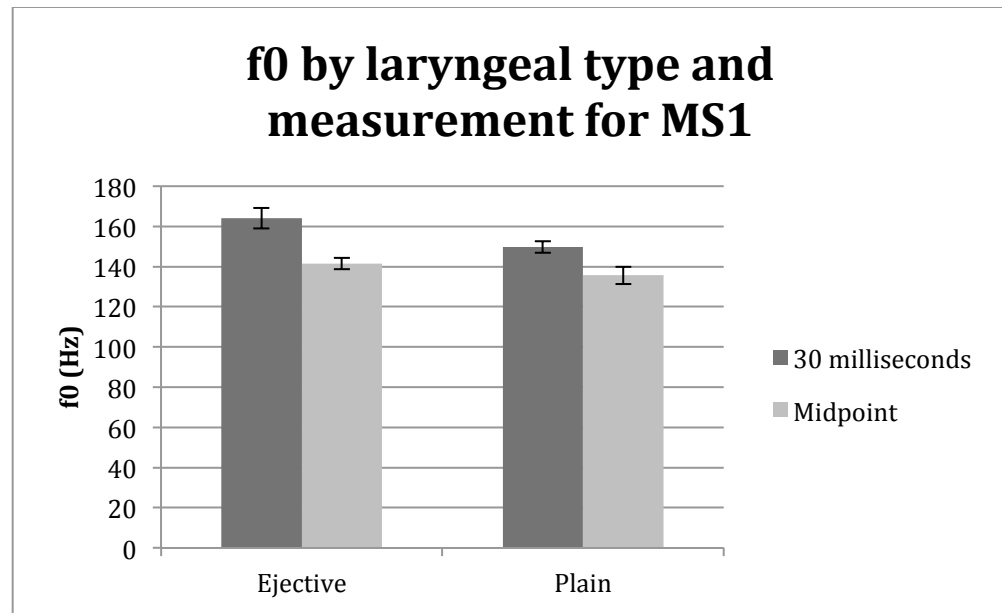


Figure 11 Mean f0 at 30ms into the vowel and at the midpoint of the vowel for MS1. Error bars show standard error.

The data for MS2, Figure 12, is not significant, though it does follow the pattern seen in MS1. The mean f0 at 30ms for the ejectives is 156.42Hz and at the midpoint is 133.58Hz. The mean f0 at 30ms for the plain obstruents is 152.00Hz and at the midpoint is 137.61Hz. The higher f0 for the ejective supports and analysis of a stiff ejective.

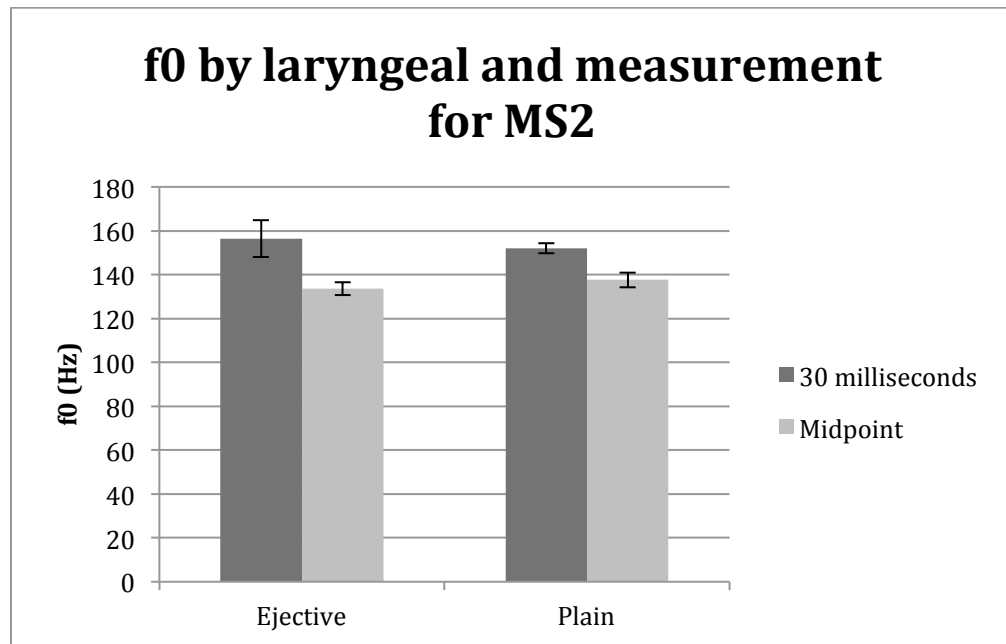


Figure 12 Mean f0 at 30ms into the vowel and at the midpoint of the vowel for MS2. Error bars show standard error.

The men show a faster rise time for the ejectives than for the plain obstruents. In addition, MS1 displays a rise time for the ejectives that is negligibly different from the rise time of the plain obstruents, as seen in Figure 13. The mean intensity at 30ms for ejectives is 68.01dB and at the midpoint is 73.09dB. The mean intensity at 30ms for plain obstruents is 67.19dB and at the midpoint is 71.94dB. This minimally faster rise time would point to a stiff ejective, though not strongly.

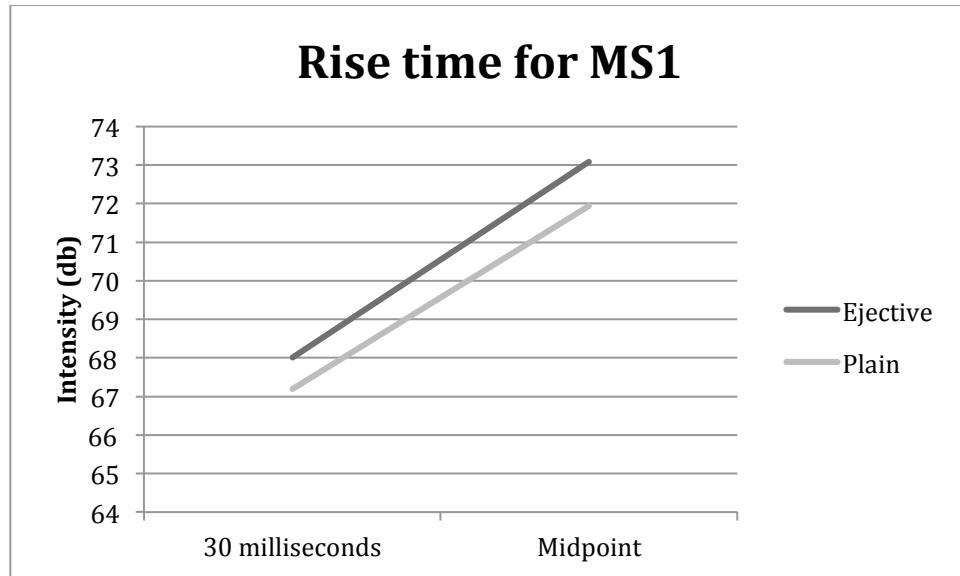


Figure 13 Mean intensity at 30ms into the vowel and at the midpoint of the vowel for MS1.

The data for MS2, Figure 14, are unique because the intensity decreases significantly from the word initial to the word medial position [$F(1, 30)=10.74$, $p=0.031$]. This is opposite of MS1 (and the female speakers, see Table 2 on page 31). In addition the intensity of the vowels following the ejectives changes faster than the plain obstruents. The mean intensity at 30ms for ejectives is 156.42dB and at the midpoint is 133.58dB. The mean intensity at 30ms for plain obstruents is 152.00dB and at the midpoint is 137.61dB. This faster change in intensity for the vowels following the ejectives provides additional support for an analysis of a stiff ejective.

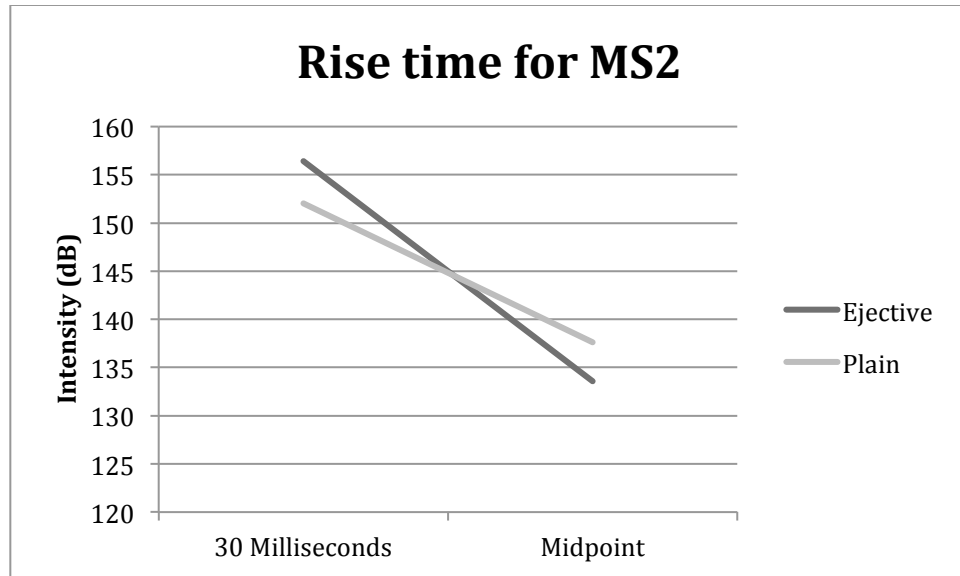


Figure 14 Mean intensity at 30ms into the vowel and the midpoint of the vowel for MS2.

The data for both MS1 and MS2 are not clear, however I would say that they support a stiff ejective analysis, though I would like to further investigate the decrease in intensity seen in MS2.

While the results I've discussed thus far generally support a stiff ejective analysis, the voice quality displayed by both male speakers is representative of a slack ejective. The jitter¹² measurement at 30ms into the vowel is larger for the ejectives than for the plain obstruents, as is seen in Figure 15 for MS1 and Figure 16 for MS2. Though the jitter is less word-midially for both the ejectives and the plain obstruents, there is less change in the measurements for the plain obstruents. In addition the jitter for the ejective is still higher than the plain obstruents. There is also more variation in the jitter for the ejectives, as is shown by the standard error

¹² Jitter is the average duration between glottal pulses.

bars. I would expect more variation in creaky phonation than in modal phonation as creak is inherently variable.

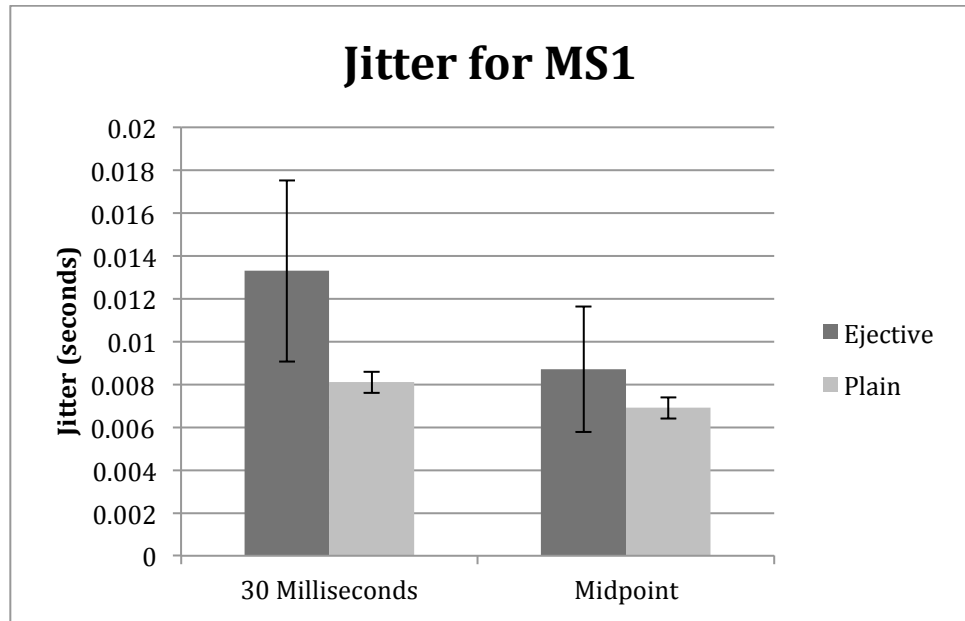


Figure 15 Mean values for jitter in seconds for MS1. Error bars show standard error.

MS1 showed a significant difference between the measurement at 30ms and at the midpoint of the vowel [$F(1, 43)=355.86, p<0.001$], meaning that the phonation showed a significant change from creaky phonation to a more modal or less creaky phonation word-medially and that there is a difference between the ejectives and plain obstruents. Jitter for ejectives at 30ms is 0.0135 seconds and at the vowel midpoint is 0.0088 seconds. Jitter for plain obstruents at 30ms is 0.0082 seconds and at the vowel midpoint is 0.0071 seconds.

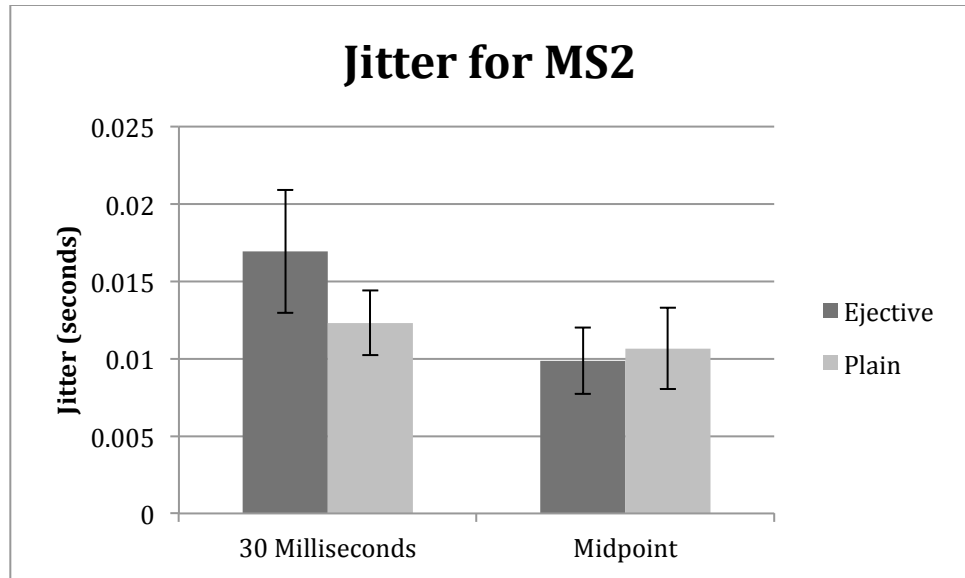


Figure 16 Mean values for jitter in seconds for MS2. Error bars show standard error.

The data for MS2 is not significant, though he does show a similar pattern to MS1. Jitter for ejectives at 30ms is 0.0200 seconds and the vowel midpoint is 0.0099 seconds. Jitter for the plain obstruents at 30ms is 0.0123 seconds and the vowel midpoint is 0.0115 seconds.

Looking at the data of the men and the women (from Nelson 2010) together provide us a better understanding of the ejectives and plain obstruents in Nez Perce. In general the men pattern together and the women pattern together. Table 2 shows the results of all speakers discussed in this study.

Overall the women show more features of slack ejectives than the men. MS2 is the only speaker who shows more features of stiff ejectives than slack ejectives.

Table 2 Results from MS1 and MS2 and Nelson 2010 (10). Bold font with * indicate significant results. Parenthesis indicate word-medially significant results. Italicics indicate descriptive statistics.

	FS1	FS2	FS3	MS1	MS2
VOT	Stiff**	Stiff**	Stiff**	Slack	Stiff*
Burst amplitude	Slack*	Slack	Slack*	Slack	Slack
f0	(Slack)*	<i>Slack</i>	Slack*	Stiff***	<i>Stiff</i>
Rise time (intensity)	(Slack)*	<i>Stiff</i>	(Slack)*	Stiff*?	<i>Stiff</i>
Voice quality	<i>Slack</i>	<i>N/A</i>	<i>Slack</i>	Slack***	<i>Slack</i>
Number of stiff features	1	2	1	2	3
Number of slack features	4	2 ¹³	4	3	2

In general, Nez Perce speakers display more features of slack ejectives that stiff ejectives. To summarize all the features seen in Table 2, FS1, FS2, FS3 and MS1 produce slack ejectives and MS2 produces stiff ejectives. It is still more important to

¹³ Note that I was previously unable to obtain data for jitter for FS2 as she tended to devocalize the first portion of her vowels. The number of features for her is only four where the other speakers all have five.

consider all of the individual features rather than collapsing them, but in general Nez Perce displays more features that are representative of slack ejectives.

2.3.1.1. Place dependent VOT

Place dependent VOT is common cross-linguistically, with the VOT increasing as the POA becomes more dorsal. Maddieson (2001) investigated Nez Perce place-dependent VOT in both plain and ejective stops. His results, based on data from five speakers, are shown in Figure 17. Based on this data Nez Perce plain stops follow place-dependent VOT. The plain bilabial stop has the shortest VOT, with the following plain stops being progressively longer until the uvular, which has the longest VOT for the plain stops. Maddieson finds a significant difference between all plain stops except for /p/ and /t/.

Maddieson's data shows that the place-dependent VOT continues for the ejectives, except for the ejective uvular. As is seen in Figure 17, the ejective uvular is shorter than the ejective velar stop. The difference in VOT is not significant for any of the ejectives (Maddieson 2001).

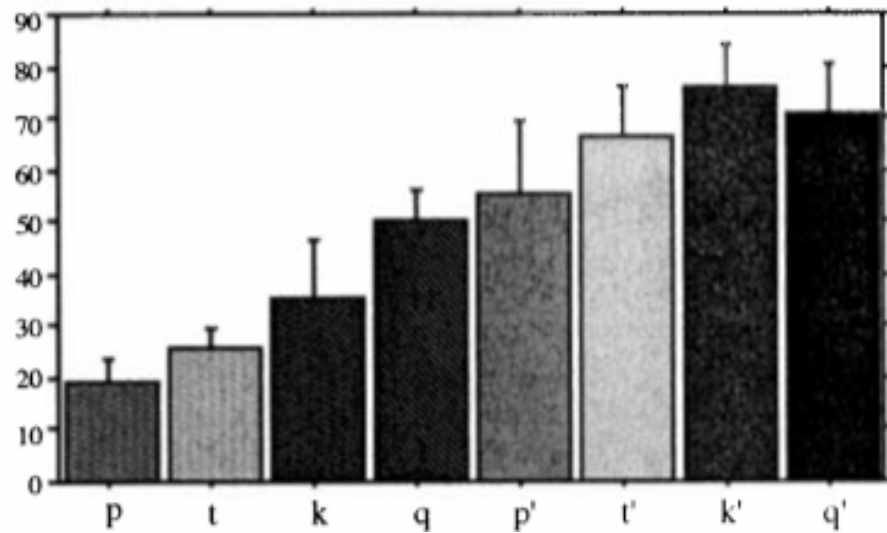


Figure 17 Mean VOT for Nez Perce ejectives measured in milliseconds, with error bars showing standard error. (Maddieson 2001: 826)

The same place dependent VOT is seen in some of the data for the Nez Perce speakers in the current study as seen in Figure 18.¹⁴ The ejective and plain obstruents of the same POA are shaded with the same color with the ejective colored in a darker shade and the plain obstruent in a lighter shade. The stops are placed in order of POA followed by a small gap and then the plain and ejective affricates.¹⁵ There are no error bars for mean VOT measurements based on one word (an average of three tokens).

¹⁴ I have also included the affricates [ts] and [ts'] in the figures because the duration of the fricative portion of the affricate varies based on whether it is a plain or ejective affricate.

¹⁵ Charts showing the plain obstruents and ejectives grouped by phonation type can be found in Appendix A.

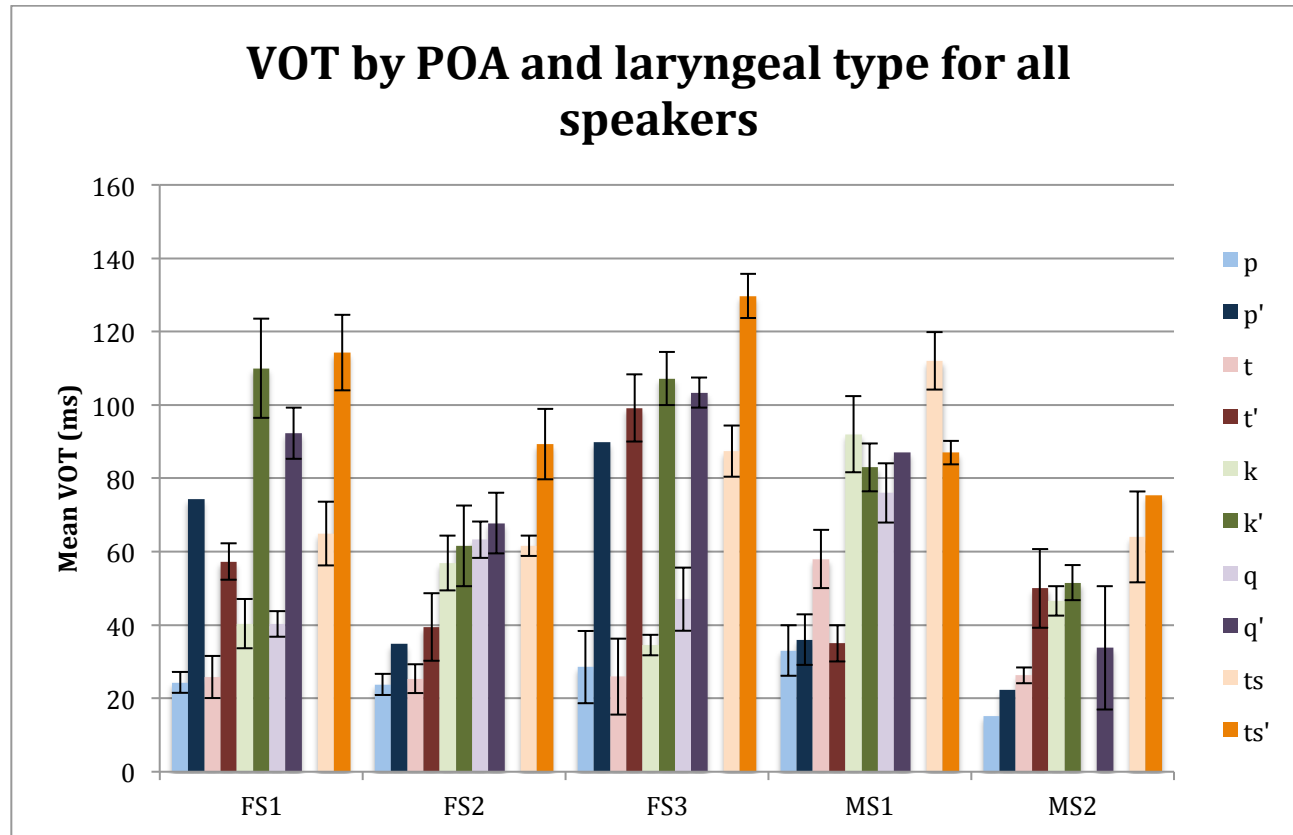


Figure 18 VOT by POA and laryngeal type for the five Nez Perce speakers. Ejective and plain obstruents of the same POA are shaded with the same color with the ejective a darker shade than the the plain obstruent. Stops are placed in order of POA followed by the affricates. Error bars show standard error.

The women show a general increase of VOT as the POA becomes more dorsal, however the men show more variation in the VOT, especially MS1. FS1, FS3, and MS2 show a VOT for [q'] that is shorter than the VOT for [k'] similar to the pattern seen in Maddieson (2001). FS2 shows a longer VOT for [q'] than for [k']. MS1 shows much more variation, with three ejectives that display shorter VOT than their plain counterparts: [t'], [k'], [ts'].

Overall, Nez Perce follows place dependent VOT, however there are some exceptions. For four of the five speakers the ejective affricate is longer than the plain affricate as we would expect to see when comparing ejective and plain consonants.

2.3.1.2. Phonotactic variation in VOT

Aoki wrote in his dissertation that the VOT for Nez Perce stops varies based on whether the phoneme is in a consonant cluster, word initial, before a vowel, or word final (1965). The following two figures (Figure 19 and Figure 20) show this variation in VOT based on the surrounding environment.

Figure 19 does not show a large difference between the word-initial and word-medial [k']. The initial onset of the word-medial ejective does show a sharper onset than the word-initial ejective. The [p] in the consonant cluster word-medially shows a smaller burst amplitude and duration of the VOT than the word-final [p].

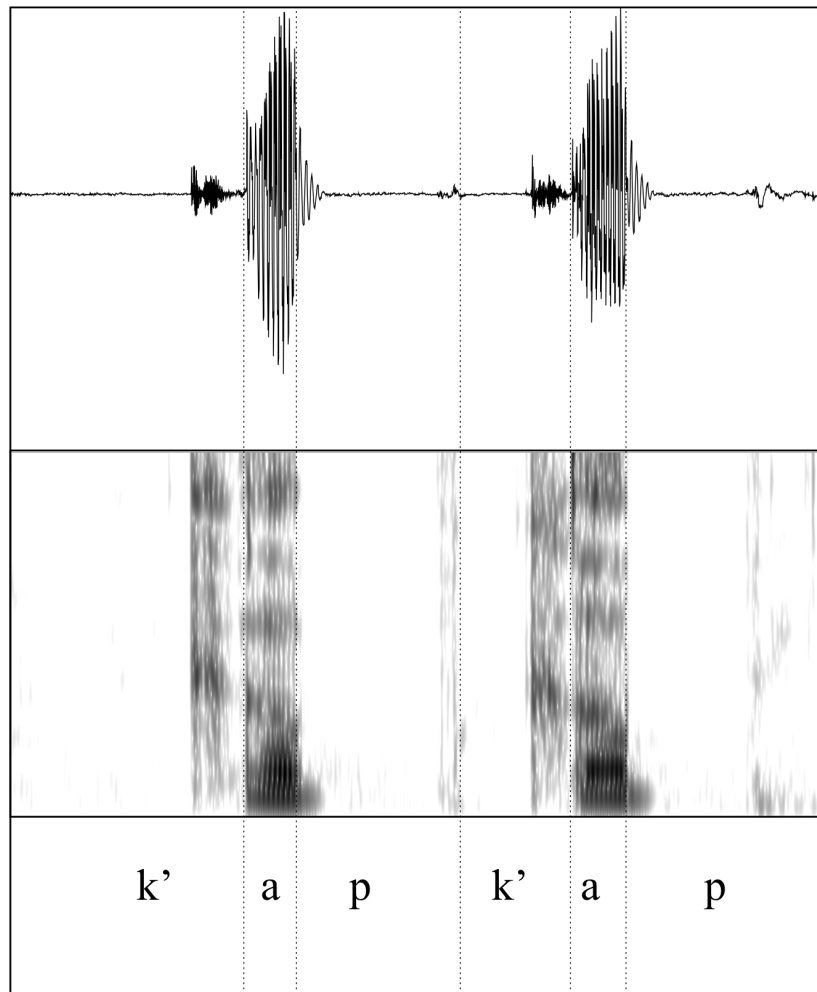


Figure 19 *K'apk'ap* 'wrist' as spoken by FS2 showing initial and medial [k'] and medial and final [p].

We can further compare the word-medial and word final [p]'s in Figure 19 with those in Figure 20. Both of the stops in Figure 20 show a shorter VOT than those in Figure 19. The word-initial burst amplitude in Figure 20 is the largest of any of the bilabial stops in these figures. The word-final affricate is also stronger than the word-medial affricate.

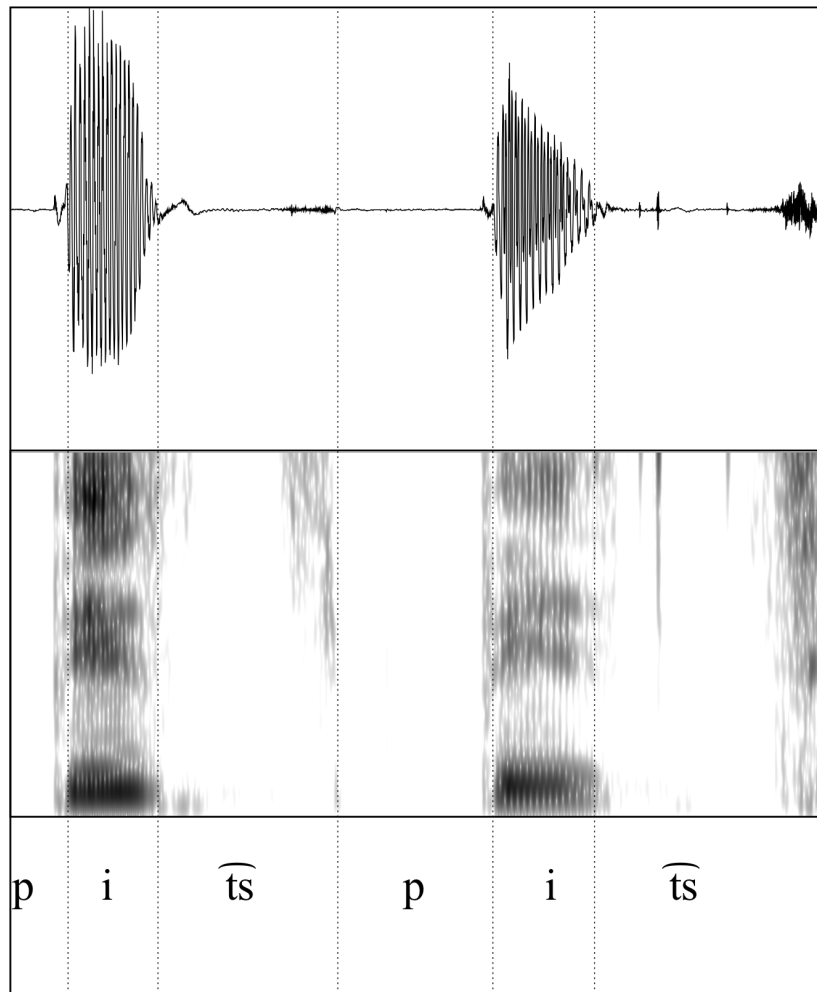


Figure 20 *Picpic*, 'cat' showing the initial and medial VOT of [p] and the affricate [ts] spoken by FS2. Word initial [p] does not show the entire stop. There was a pause between the carrier phrase and the target word.

There are some orthographic geminates in Nez Perce. I found three examples of geminates in my data. These geminates were found in '*aqqaapx*, 'backward' and *hittillaapna* 'he pined, he missed someone'. Duration measurements of the geminates and non-geminates can be seen in Figure 21. These measurements

are averaged across speakers for the lateral, alveolar and uvular. The geminates show a longer duration than the non-geminates.

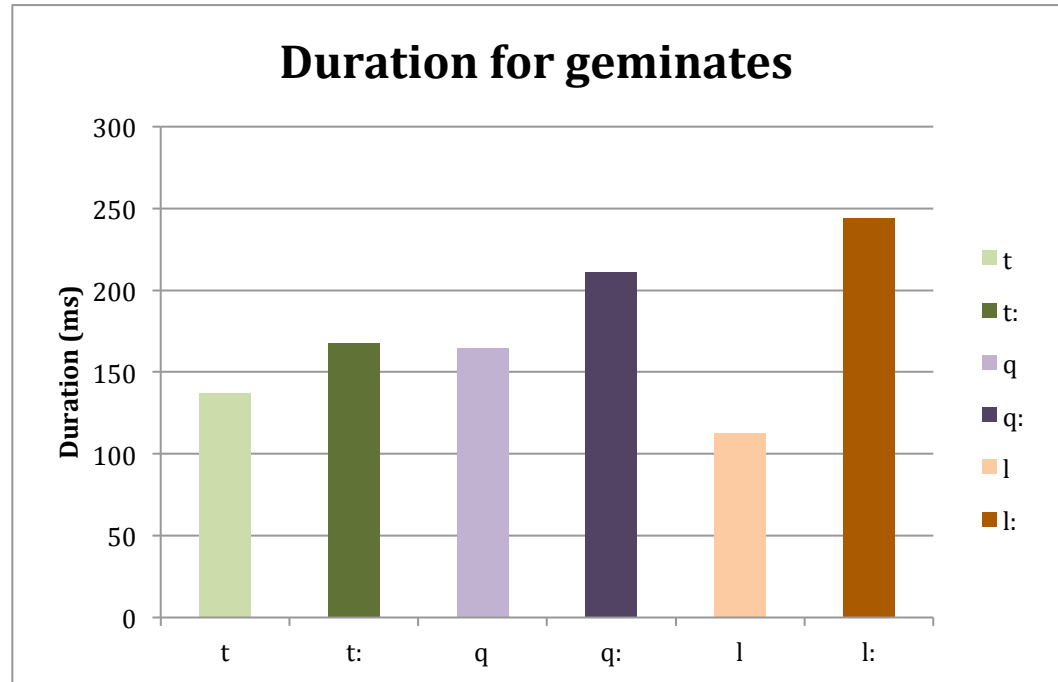


Figure 21 Duration measurements for geminates and non-geminates averaged for all speakers.

There is a larger durational difference between the geminate and non-geminate uvular than there is between the geminate and non-geminate alveolar. A possible reason for this larger durational difference is that the uvulars tend to be fricated. This can be seen in Figure 22 which shows the word-medial geminate for *'aqqaaqx, 'backward'*.

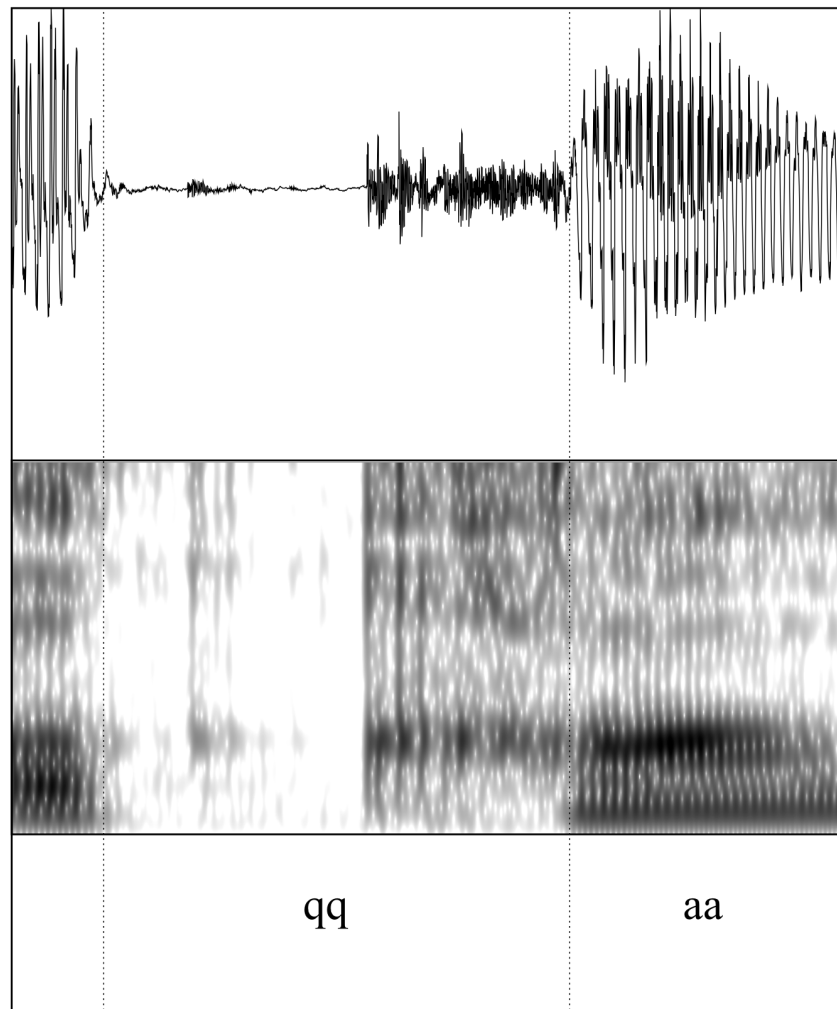


Figure 22 Gemminate uvular from *'aqqaapx* 'backward' spoken by FS2.

All of the averaged tokens are word-medial because the geminate examples I have are word-medial. I also have a very limited number of geminate tokens.

Crook (1999: 15-16) examined geminates in the language and found morphological and phonological explanations for most of the cases. He found that there are some cases where two identical consonants occur together because a short

vowel separating them is syncopated. He also found cases of what he terms “emphatic gemination.” In this process a word-initial CV syllable with a short vowel is given stress and the following consonant is lengthened. Example 1 shows this process with a word-medial glottal stop (Crook 1999: 16).

- (1) a. la’ám’ b. là’’ám’
 ‘all’ ‘absolutely all’

In addition to these processes, which explain the existence of geminates in most instances, there are also about ten words Crook cannot find an explanation for. He gives two examples of these words in his dissertation and both are geminate sonorants. In the process of my study I found one instance of a sonorant geminate, *hittillaapna* ‘he pined, he missed someone’ (mentioned above). The durational difference between the geminate and the non-geminate sonorant is greater than for the stops. Nez Perce has phonemic length for vowels, which is found in many examples. There are few examples of geminate consonants suggesting that they are not as productive or important as the phonemic vowel length. There may be a relation between the vowels and the sonorants because both have higher sonority than the stops. It is also possible that the geminates are no longer productive and may have been lost over the years.

2.3.1.3. Stop frication

There are some instances in Nez Perce of stop frication that I have observed and that have been previously described by Crook (1999: 18, 280). The plain uvular

and velar stops and the plain affricate will fricate before sonorants.¹⁶ This frication is reflected in the orthography and is shown in Example 2.^{17,18}

(2)	a. [qotsqots]	b. [qotsqosna]
	< qocqoc >	< qocqosna >
	/qotsqots/	/qotsqots-ne/
	meadowlark	meadowlark-OBJ
	‘meadowlark’	‘meadowlark (talking about it)’

The dorsal stops /k/ and /q/ also fricate word-finally as shown in Example 3 (Crook 1999: 18). This frication is again reflected in the orthography.

(3)	a. [tasχ]	b. [tasqiin]
	< tasχ >	< tasqiin >
	/tasq/	/tasq-iin/
	grease	grease-ATRB
	‘grease’	‘greasy’

I have also observed these dorsal stops fricating throughout the word in any environment.

2.3.2. Glottal stop

The glottal stop is realized in various ways depending on the location in the word. Word initially it is either not produced or is produced as glottal stops are

¹⁶ /x/ and /χ/ are also phonemes.

¹⁷ The following examples provide the [phonetic representation], <the orthography>, /the phonological information/, the morpheme-by-morpheme gloss and finally the free translation.

¹⁸ Note that this example also shows vowel harmony in the object suffix *-ne*.

commonly produced cross-linguistically. Figure 23 shows a standard word-initial glottal stop. The initial glottal pulse is clearly seen followed by the negative dip in the waveform at the beginning of the vowel.

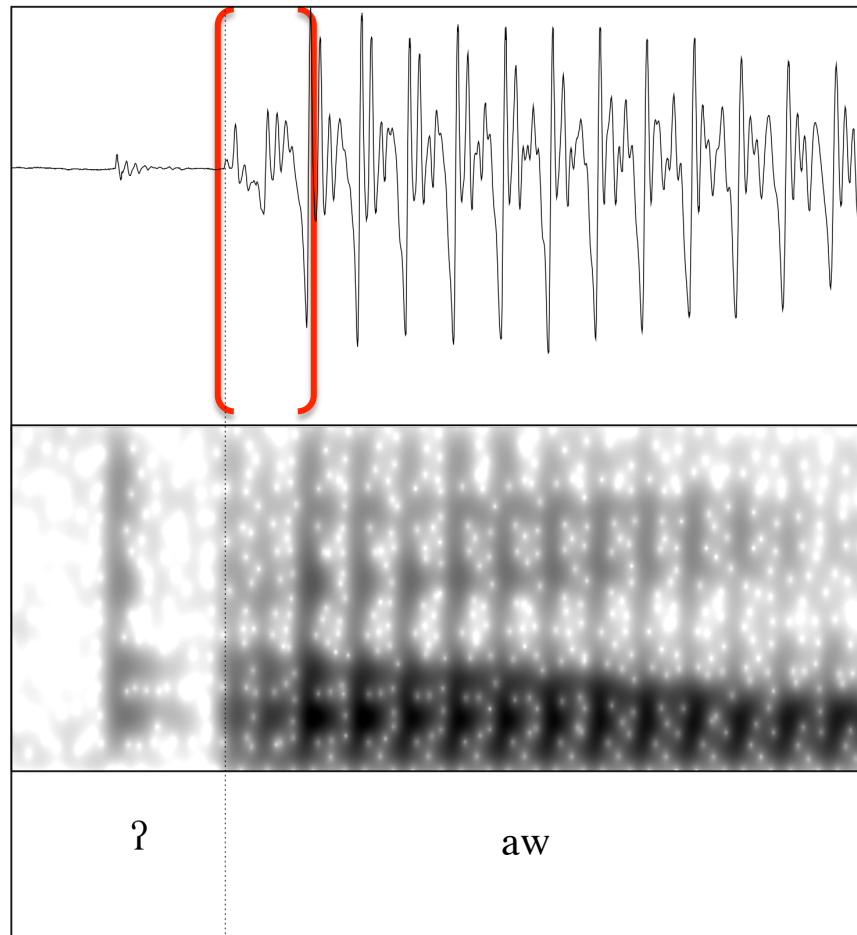


Figure 23 Word-initial glottal stop for '*aw'nak'amkitx*, 'you collect (command plural)', as spoken by FS1.

The glottal stop has multiple intervocalic realizations. The following two figures, Figure 24 and Figure 25, show two possibilities. The glottal stop is realized

as a pause between the two vowels in Figure 24. There is also some creak on the end of the preceding vowel.

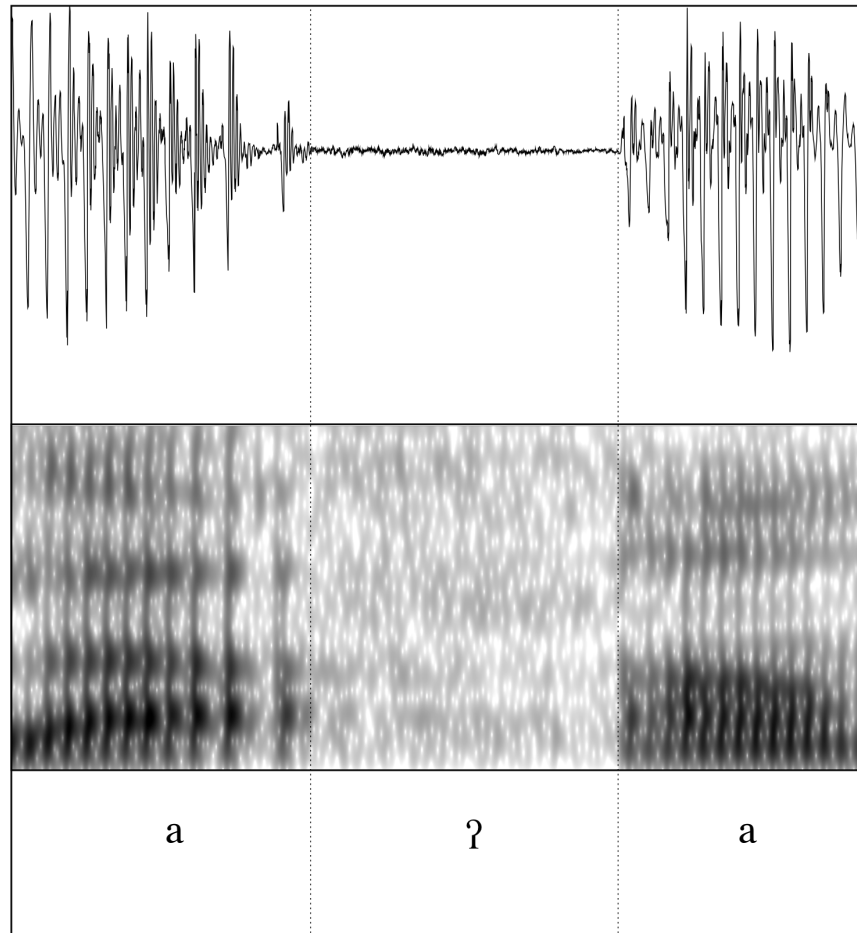


Figure 24 Intervocalic glottal stop for *la'am*, 'all', as spoken by FS1.

Figure 25 shows a glottal stop intervocalically which is nearly a pause but there is a single glottal pulse as well as creak on either side of the glottal stop.

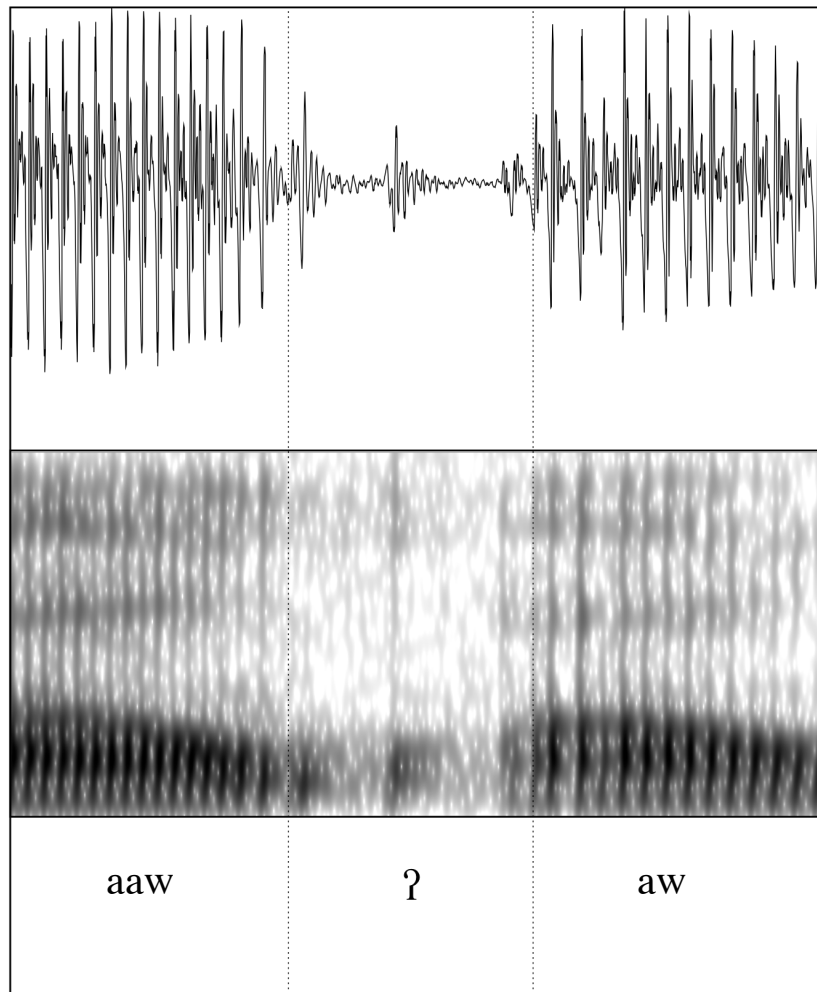


Figure 25 Intervocalic glottal stop for *cikaaw'aw*, 'easily scared, timid, cowardly' as spoken by FS1.

In addition to these two examples of intervocalic glottal stops, the glottal stop can also be realized simply as creak on the vowels, rather than a pause (or complete closure of the vocal folds).

There is a similar amount of variation seen in the word-final glottal stop. It can be realized as creak on part or the entire vowel.

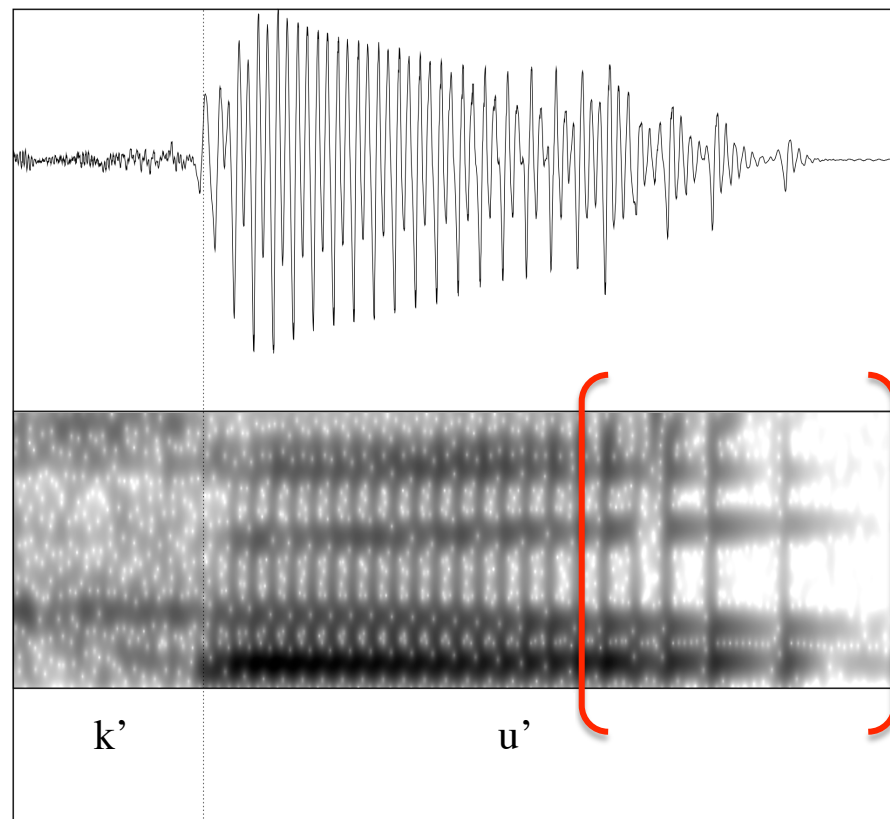


Figure 26 Word-final glottal stop for *t'ik'u'* 'yes, precisely, sure' as spoken by FS1.

Figure 26 shows the effects of a word-final glottal stop on the preceding vowel. The last portion of the vowel is produced with creak.

There are a variety of ways speakers produce word-final and intervocalic glottal stops, however the word-initial glottal stops are either produced as seen in Figure 23 or are not produced. This is similar to patterns seen in other languages. Ladefoged & Maddieson (1996: 73-77) find in their review of glottal sounds in the world's languages that there is variation in the production of glottal stops. Often word-medial glottal stops are not produced as a complete closure but as creak on

the preceding or following vowels (Ladefoged & Maddieson 1996: 74-76), which is found in Nez Perce as well.

2.3.3. Fricatives

The various places of articulation for fricatives cause concentrations of energy at different frequencies. These concentrations of energy are used to describe the differences between the fricatives. LPC spectrums were used to document the concentrations of energy in Nez Perce fricatives (Ladefoged 2003: 152-159).

Following the work by Gordon, Barthmaier & Sands (2002) and Jongman, Wayland & Wong (2000), I describe Nez Perce fricatives in terms of the spectra, duration of the fricative, formant transitions, and the four moments (center of gravity, variance, skew, and kurtosis).

2.3.3.1. Spectra

The following five spectra show examples for each of the Nez Perce fricatives. Each figure contains one example spectra from a female (red) and a male (blue) speaker. These spectra are meant to be representative of the fricative. The subsequent section (Section 2.3.3.2) discusses each of the spectral moments in detail, which is based on all of the available data for fricatives.

Overall the spectra differentiate the fricatives and to some extent the genders. Figure 27 shows the spectra for the alveolar fricative in *mac'yóosatay* 'ear hair' for MS1 and FS2. MS1 shows a concentration of energy around 3,000-4,000 Hz while FS2 shows a concentration of energy around 5,000 Hz. We would expect to

see this difference in hertz between male and female speakers due to the smaller oral cavity in women (Johnson 2003: 125). In addition the energy is fairly evenly distributed throughout the spectrum and the spectrum is not very peaked.

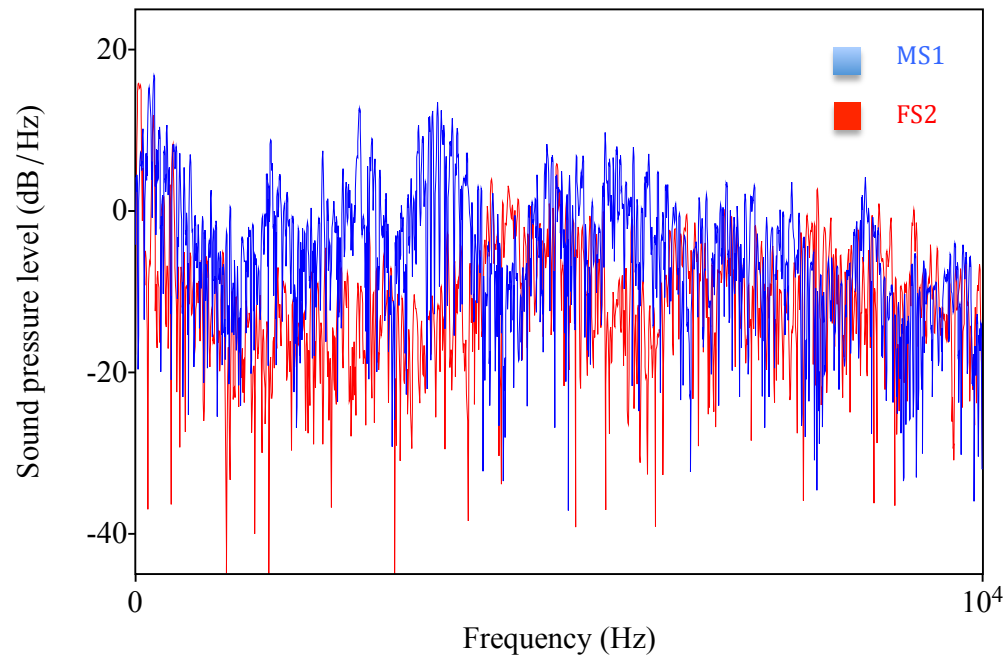


Figure 27 MS1 (blue) and FS2 (red) for [s].

Figure 28 shows an examples of the word-medial lateral fricative in *téptep* 'butterfly' for MS1 and FS3. MS1 shows an initial peak in the spectrum around 1,300 Hz while FS3 shows a peak in the spectrum around 2,000 Hz. Both speakers show more energy in the lower frequencies. The spectra are not highly peaked similar to the spectra for the alveolar fricative.

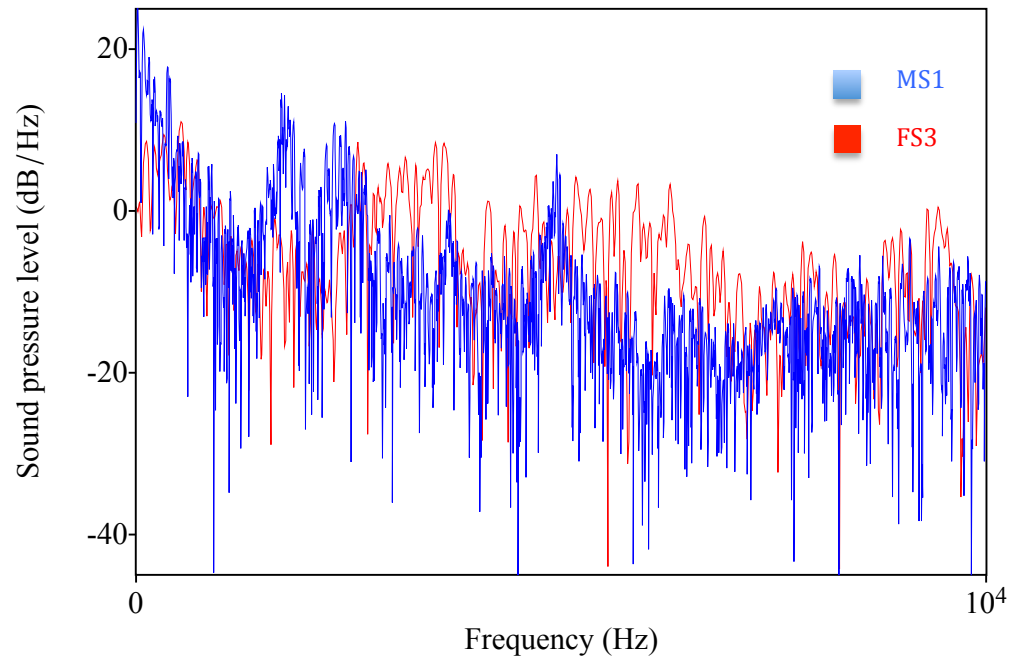


Figure 28 MS1 (blue) and FS3 (red) for [ɬ].

Figure 29 shows an example of the word-medial velar fricative in *xiwíwxíwiw* ‘cut, gashed’ for FS2 and the third velar fricative in *xixáwxixaw* ‘stretched tight’ for MS2. Both speakers show similar peaked spectrums around 1,300 Hz, however FS2 shows a second peak around 4,000 Hz where MS2 shows a dip in the spectrum, but peaks later around 4,500Hz. The spectra are also more peaked than those seen for the alveolar and the lateral fricatives, however, the energy is concentrated in the lower frequencies.

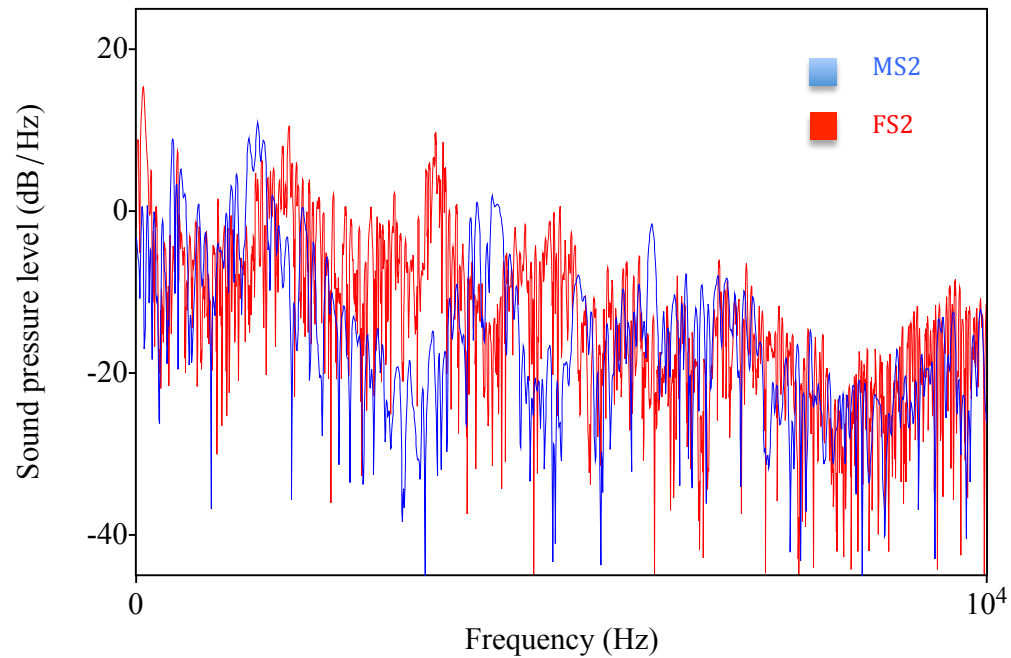


Figure 29 MS2 (blue) and FS2 (red) for [x].

Figure 30 shows an example of the uvular fricative in ‘*όypαχloo*’¹⁹ ‘all five’ for MS2 and FS1. Both speakers show similar spectral peaks around 1,300 Hz, though the peaks are not that strong. In addition, the spectra show a concentration of energy in the lower frequencies.

¹⁹ Orthography <‘*όypαχloo*>

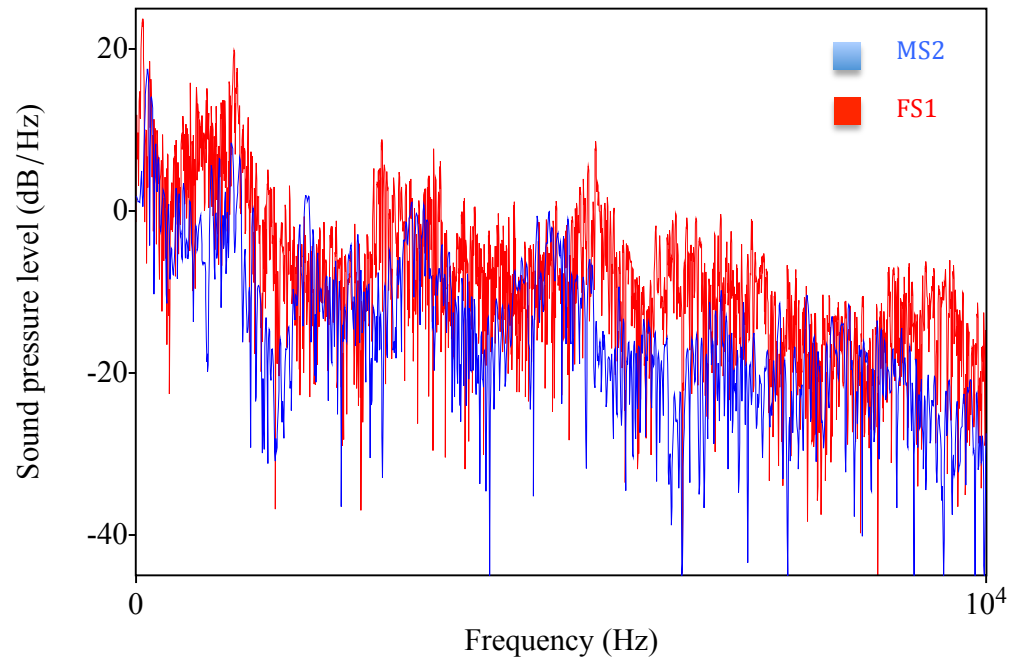


Figure 30 MS2 (blue) and FS1 (red) for [χ].

Figure 31 shows an example of the glottal fricative in *yéhet* ‘neck’ for FS2 and in *téhes* ‘ice’ for MS2. FS2 shows a relatively flat spectrum with few peaks, while MS2 shows a spectrum with many peaks. Both speakers also show a concentration of energy in the lower frequencies, with MS2 showing lower frequencies than FS1.

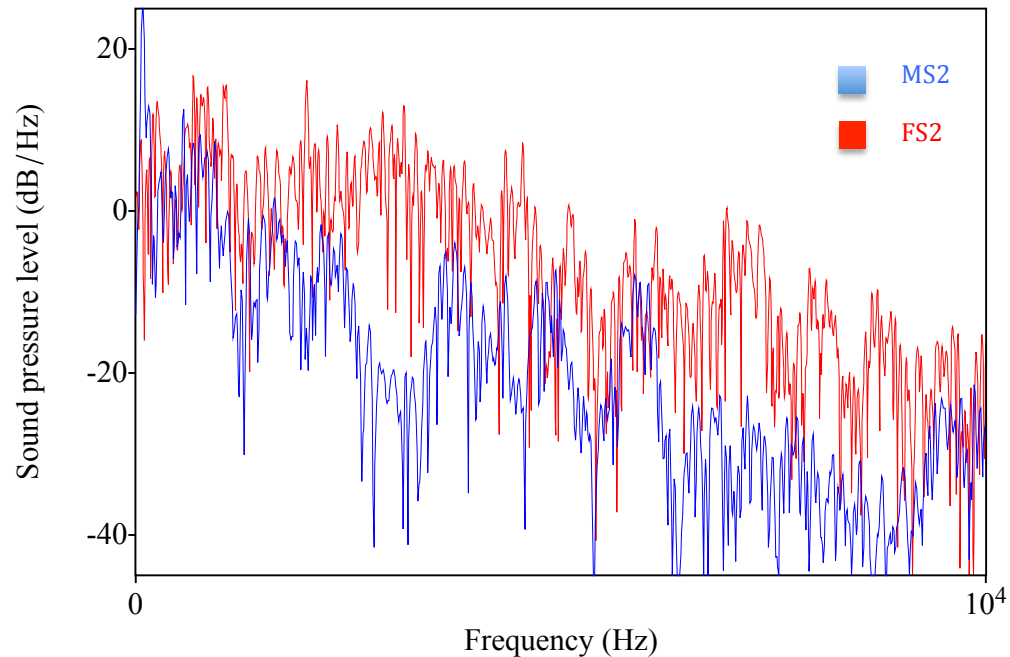


Figure 31 MS2 (blue) and FS2 (red) for [h].

In general the spectra showed differences between the fricatives and to a lesser extent the genders. As these are not averaged spectra, they are intended to be representative of the fricatives and speakers in general. Some of the differences discussed above would average out if averaged spectra were used, as will be seen in the following discussion in Section 2.3.3.2. To support the discussion in this section about the spectra, the subsequent section will provide an analysis of the Nez Perce fricatives using more data and detailed descriptions of the various moments, duration, and intensity of the fricatives.

2.3.3.2. Spectral moments

Jongman, Wayland & Wong (2000: 1253-1254) discuss the four spectral moments. The first moment or the center of gravity (centroid) shows where the average concentration of energy for each fricative is located in the spectrum (Jongman, Wayland & Wong 2000: 1253-1254). As seen in Figure 32, FS1, FS2, FS3, and MS1 all show a similar pattern.

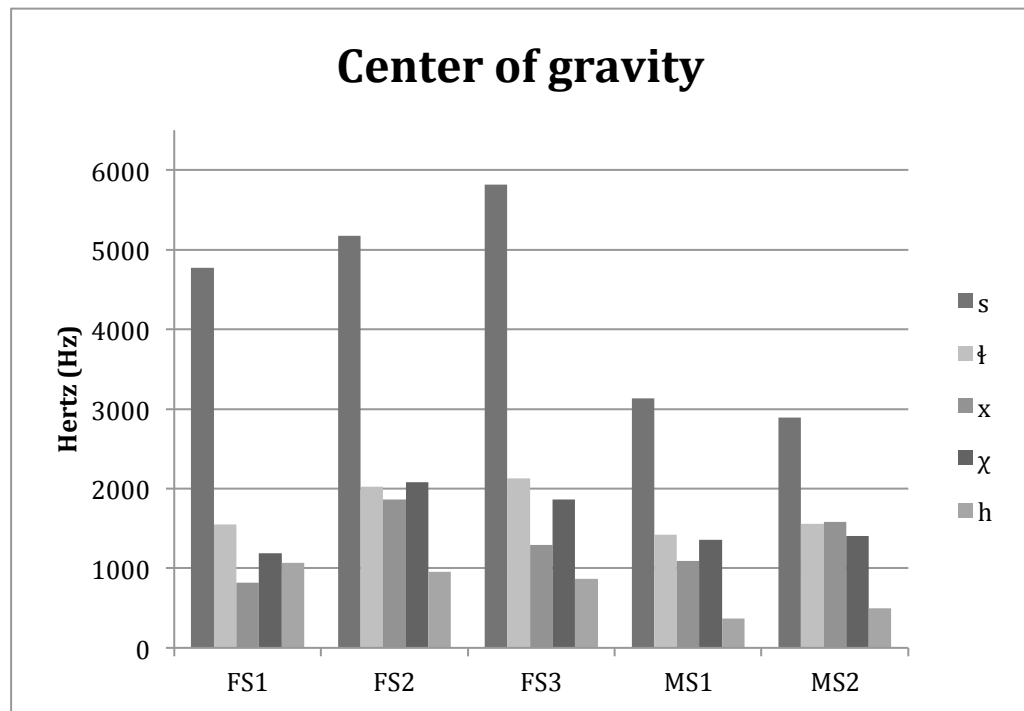


Figure 32 First moment or center of gravity for the five Nez Perce speakers by fricative.

The alveolar fricative displays the highest center of gravity, indicating that the average concentration of energy is highest for the alveolar fricative for these speakers. The fricative with the next highest center of gravity is the uvular fricative,

followed by the lateral fricative, then the velar and finally the glottal fricative has the lowest center of gravity. MS2 also follows this described pattern to an extent, however the velar fricative has a higher center of gravity than the lateral and uvular fricatives. These results are expected because the smaller the area for turbulence in the oral cavity, the higher the frequency (Johnson 2003: 125). We see this with the decreasing frequency the more dorsal the fricative.

The second moment, or the variance, also describes the concentration of energy and its distribution in the spectrum (Jongman, Wayland & Wong 2000: 1253-1254). The variance data is outlined in Figure 33.

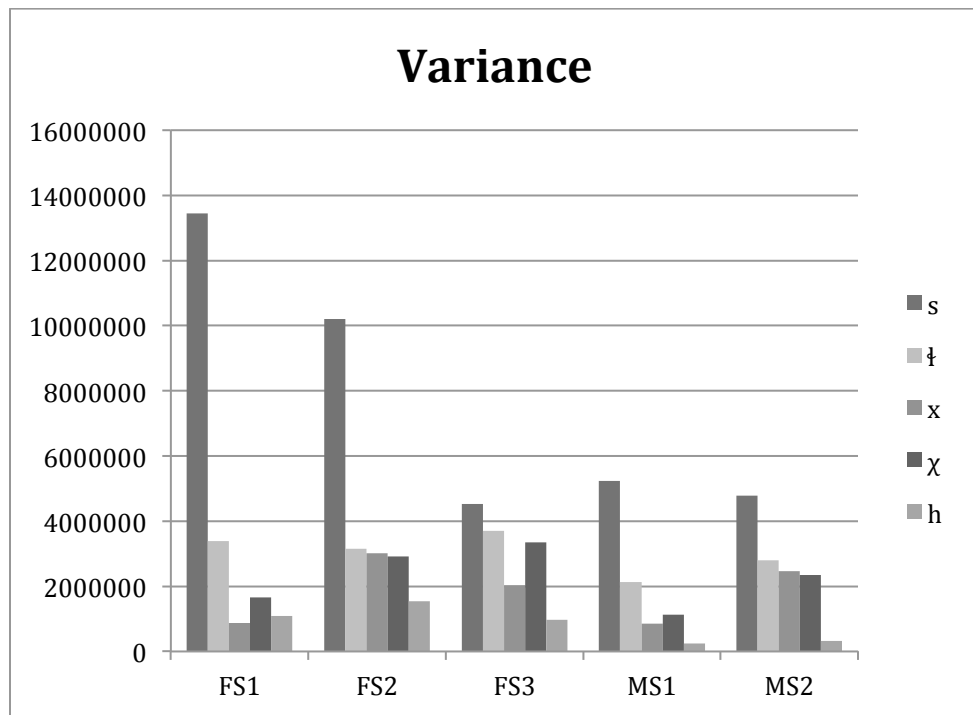


Figure 33 The second moment or the variance for the five Nez Perce speakers by fricative.

All of the speakers show similar patterns. MS2 and FS2 both show a general decrease in the variance the more dorsal the fricative becomes. FS1, FS3, and MS1 also show this general pattern, however there is a “bump” at the uvular fricative, which could also be seen as a “dip” at the velar fricative. Overall the variance decreases the more dorsal the stop becomes.

The third moment or the skew (spectral tilt) as discussed by Jongman, Wayland & Wong (2000: 1253-1254), indicates the distribution of the noise in the spectrum. They write that if the skew is zero, then the energy is symmetrically distributed around the mean. Furthermore, if the skew is positive then the energy is located in the lower frequencies, showing a negative spectral tilt, and if the skew is negative then the energy is located in the higher frequencies, showing a positive spectral tilt.

All speakers, as seen in Figure 34, show a positive skew meaning the energy is concentrated in the lower frequencies. Each speaker utilizes this positive skew to varying degrees for the different fricatives.

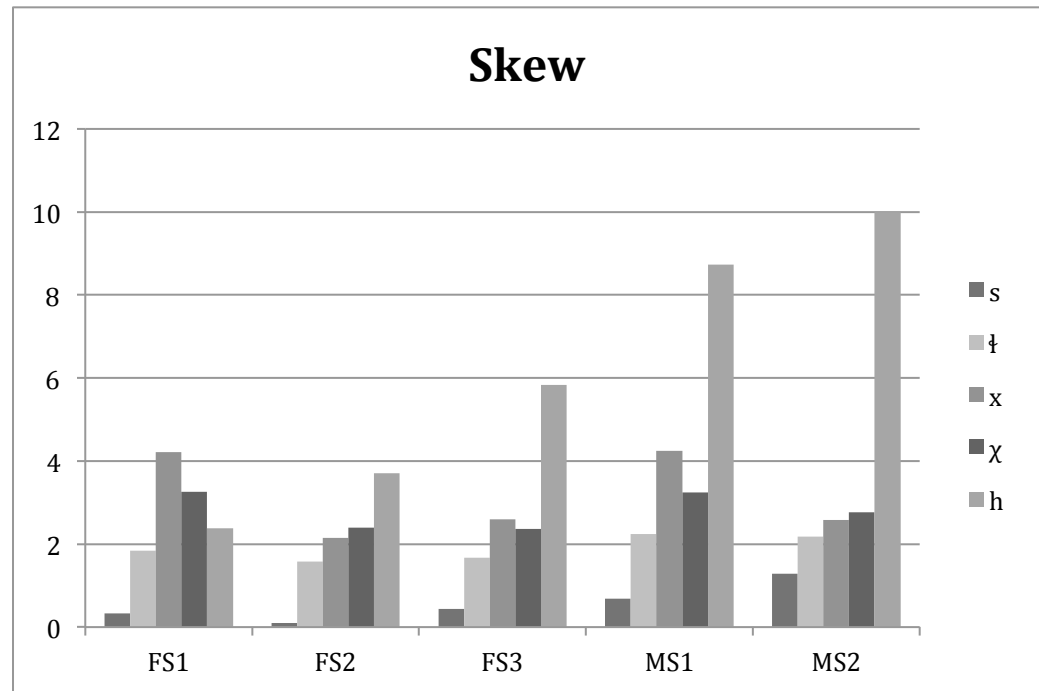


Figure 34 The third moment or the skew for the five Nez Perce speakers by fricative.

In general there are three patterns for the skew. FS2 and MS2 both show a general increase in the skew the more dorsal the fricative becomes, meaning the energy is increasingly concentrated in the lower frequencies the more dorsal the fricative, as was seen in the spectra in Section 2.3.3.1. FS3 and MS1 both show a similar increase in the skew the more dorsal the fricative becomes, however the velar fricative shows more positive skew than the uvular fricative. FS1 shows the same bump in the velar fricative, however the glottal fricative shows a smaller positive skew than her uvular fricative and a smaller positive skew than the glottal fricatives seen in other speakers. Overall the glottal fricative shows the highest positive skew, except for FS1. The alveolar fricative has the lowest skew for all speakers, indicating a concentration of energy in the higher frequencies.

The fourth moment or the kurtosis describes the sharpness of the energy peaks (Jongman, Wayland & Wong 2000: 1253-1254). A positive kurtosis is associated with stronger energy peaks. A negative kurtosis is associated with a flatter energy distribution as less defined energy peaks. The kurtosis can be seen in Figure 35.

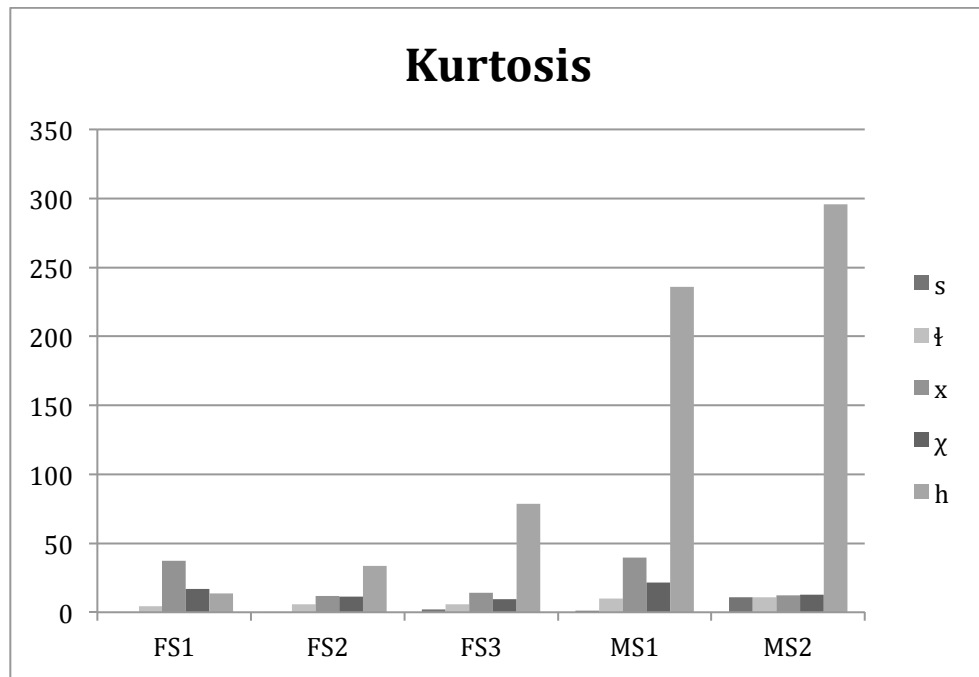


Figure 35 The fourth moment or the kurtosis for the five Nez Perce speakers by fricative.

FS2, FS3, and MS1 all pattern together. The more dorsal the fricative becomes the higher the kurtosis, with a small bump in the velar fricative. This increase in kurtosis means that the more dorsal the fricative the more clear the spectrum and the peaks. All speakers except FS1 show the highest kurtosis in the glottal fricative. The alveolar fricative has the lowest kurtosis value and the flattest spectrum with the least defined peaks.

2.3.3.3. Duration

In addition to the moments, the overall duration was studied. Results show that generally, the more dorsal the POA of the fricative, the shorter the duration of the fricative. The speakers do not all follow the same durational patterns for the different fricatives, however there is a pattern that three speakers follow and a fourth shows a similar pattern. The fifth speakers, however, is quite different from the others. These durational patterns can be seen in Figure 36.

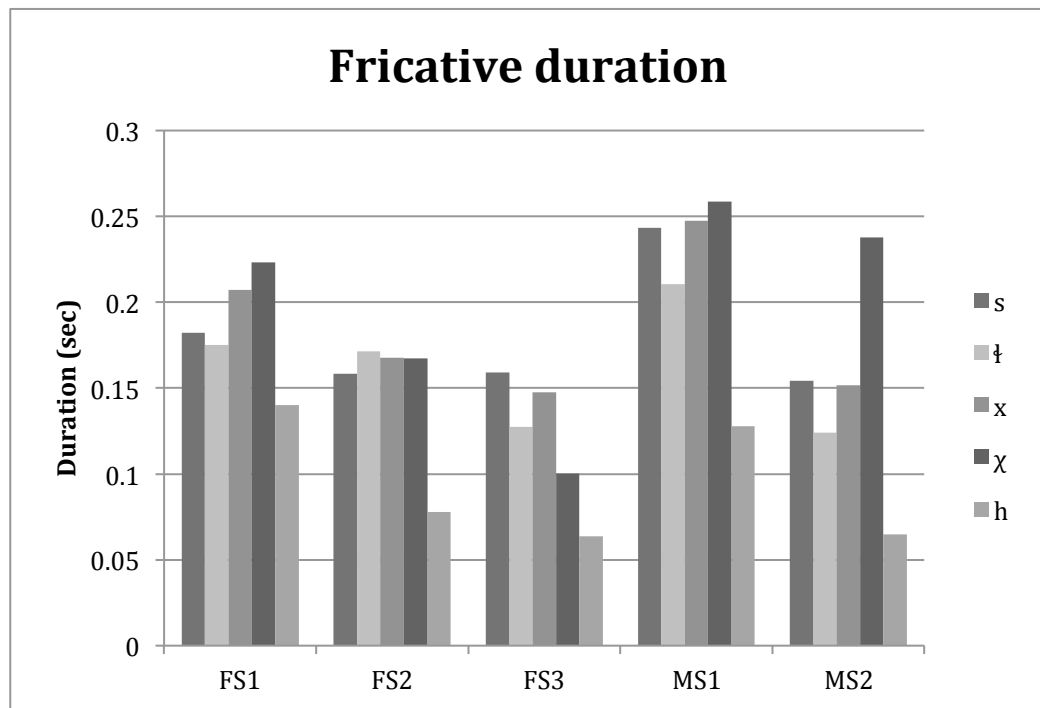


Figure 36 Durational patterns for the Nez Perce fricatives for each of the five speakers.

FS1, MS1, and MS2 all show similar durational patterns for the fricatives. The longest fricative is the uvular fricative, followed by the alveolar and velar fricatives. The next longest is the lateral fricative and the shortest fricative is the glottal fricative. FS3 also follows a similar pattern except that the uvular fricative is

shorter than the velar fricative. FS2, however, shows a very different durational pattern. Her alveolar, lateral, velar and uvular fricatives are all about the same duration. Her glottal fricative is the shortest fricative, similar to all of the other speakers.

Generally speakers showed an increased duration the more dorsal the fricative. There is, however, one significant exception to the generalization of the dorsal length interaction: the duration of the uvular fricative. The uvular fricative is the longest fricative for three of the five speakers.

2.3.3.4. Intensity

The different types of fricatives, stridents and non-stridents, show varying levels of intensity, with stridents having a higher intensity level than the non-stridents (Ladefoged 2005: 167). The Nez Perce fricatives, however, do not follow this generalization, as seen in Figure 37.

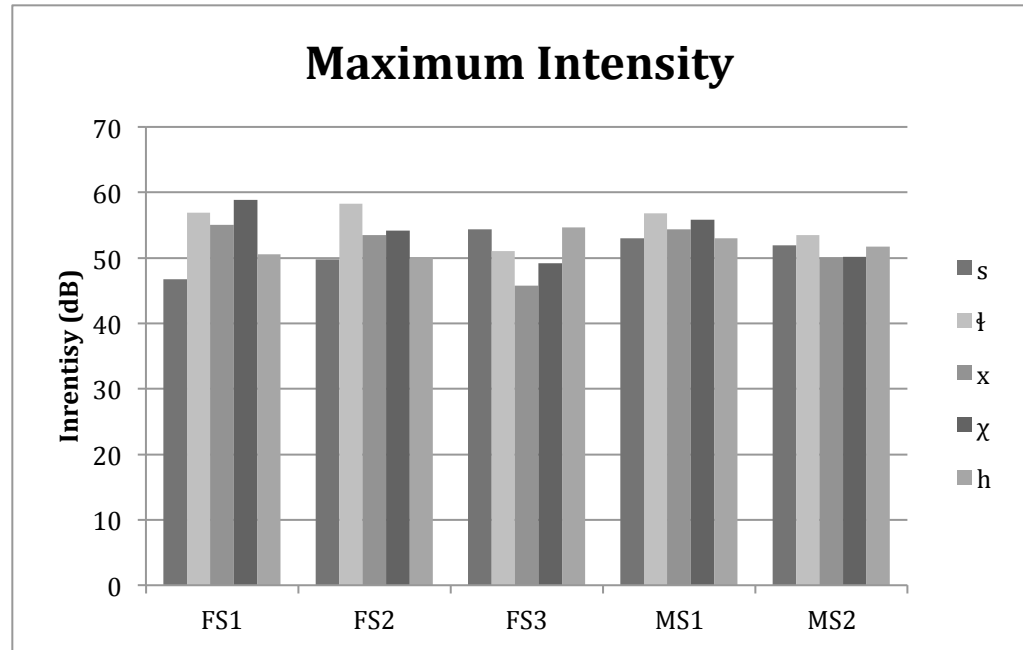


Figure 37 Maximum intensity for the Nez Perce fricatives for each of the five speakers.

FS1, FS2, and MS1 pattern together, with all three speakers showing the same up-down-up-down pattern. The lateral shows a higher intensity than the alveolar, the velar is lower than the lateral, the uvular is higher than the velar and the glottal is lower than the uvular. MS2 displays a very similar pattern with the exception of the uvular fricative, which is similar to the velar. FS3 shows a different pattern with the velar fricatives showing the lowest intensity.

As previously mentioned in Section 2.1 there are four non-strident fricatives, /t x χ h/, and one strident fricative, /s/, in Nez Perce. In general strident fricatives show a higher intensity than the non-strident fricatives (Ladefoged 2005: 167). The alveolar fricative in Nez Perce should therefore show a higher intensity, but this is not the case.

Overall, Nez Perce fricatives do not display a pattern based on the strident and non-strident fricatives, though, FS1, FS2, MS1, and to an extent MS2 do show similar patterns across the fricatives.

2.3.3.5. Formant transitions

Nez Perce displays the standard formant transitions²⁰ from the fricative to the following vowel. These transitions are not always clear, however, those that are clear generally displayed the transitions seen in stops of the same place of articulation. The alveolar fricatives show transitions similar to the transitions seen in alveolar stops and the velar fricative also shows transitions similar to velar stops, displaying the velar pinch. Vowels following the glottal fricative show no formant transitions because the glottal fricatives are produced as voiceless vowels.

2.4. Summary

This chapter provided a discussion of the Nez Perce obstruents beginning with the stops, affricates and ejectives; and finishing with the fricatives. The results show that the ejectives have characteristics associated with slack ejectives similar to the previous results from my 2010 study, however the two men in the current study did show some differences in the intensity and the f0. The results for the intensity and the f0 were both suggestive of stiff ejectives, unlike the data for the three

²⁰ The data presented here was gathered by visually inspecting the transitions. Another detailed study should be conducted focusing on the formant transitions and their role in perception for Nez Perce speakers.

women. MS2 showed more features of stiff ejectives than slack ejectives, while the other speakers showed more features of slack ejectives than stiff ejectives.

Generally, speakers show more features of slack ejectives than stiff ejectives.

Nez Perce fricatives showed formant transitions consistent with those seen in stops of the same POA. The alveolar fricative showed the highest center of gravity and variance while the glottal fricatives showed the greatest skew and kurtosis. The duration was not a good indicator of the fricative except for the glottal fricative, which showed the shortest duration in all speakers. Intensity was also not helpful in differentiating the fricative.

The features summarized above allowed for a complete description of the consonants as well as for cross-linguistic comparisons and provide a clear understanding of Nez Perce obstruents.

Chapter 3

Plain and glottalized sonorants

Glottalized sonorants are relatively rare segments in the world's languages (Maddieson 1984). Nez Perce is one of these languages, displaying five plain and five glottalized sonorants. These segments are investigated to determine the gestural timing of the glottalization. All sonorants are discussed using rate of change (glides), gestural timing of glottalization (all segments), and how glottalization is realized (all segments). Additionally, I discuss pitch differences seen in glottalized segments and duration measurements.

3.1. Background

The Nez Perce language has both a plain and glottalized sonorant series. It has the plain nasals /m n/, glides /w j/, liquid /l/ and the corresponding glottalized

sonorants /m n w j l/.²¹ Maddieson (1984) discusses the rarity of these glottalized segments as well as the relative frequency of the plain sonorants as exemplified in the languages of UPSID.²²

Plain voiced laterals are the most common lateral cross-linguistically, representing 74.7% of the laterals (313 plain laterals of 333 laterals in the UPSID database) (Maddieson 1984: 74). In addition 86.1% of languages in the database have /j/, 75.7% of languages have /w/, and together they occur in 65.2% of the languages surveyed (91).

While these plain sonorants are fairly common, the glottalized sonorants are relatively uncommon in the world's languages. Of the 317 languages Maddieson (1984) studied, only twenty (6%) have glottalized sonorants in the language. Glottalized sonorants generally occur in languages that also have ejectives (Maddieson 1984). Supporting this generalization, of the twenty languages with glottalized sonorants in Maddieson's study, 19 also have ejectives. Only 2.6% of the languages in the study have voiced glottalized laterals (Maddieson 1984: 74), 4.1% have voiced glottalized palatal approximants, and 3.8% have voiced glottalized

²¹ Normally glottalization would be indicated below the segment as seen with [w̥], however marking the glottalization this way for the palatal glide would not be seen so it is marked above the segment [j̥].

²² Maddieson uses UPSID, the UCLA Phonological Segment Inventory Database, which is a collection of 317 languages in his 1984 book, *Patterns of Sounds*, to describe generalizations about consonant inventories of the world's languages, including Nez Perce.

labiovelar approximants (93). In addition, glottalized nasals do not occur in a language unless there is a corresponding plain nasal series (65).

The realization of glottalization on sonorants varies language-to-language, segment-to-segment, and location-to-location in the word (Kingston 1985; Um 1998, 2001). In a study of 17 languages, including Nez Perce, Um (2001) finds that (i) “syllable-initially glottalized sonorants are mostly preglottalized, and never postglottalized” and (ii) “syllable-finally glottalization is variably realized on any part of the sonorant” (349). She finds that this describes Nez Perce where glottalized sonorants occur word-finally or syllable-finally and the realization of the glottalization varies (Um 2001: 339). These findings are similar to Kingston’s (1985) generalizations about timing and glottalization.

Um (1998, 2001) studied glottalized sonorants to understand the gestural timing of the glottalization. She finds that the glottalization varies in Nez Perce (1998: 101). Kingston (1985) also discussed glottalized sonorants in his dissertation on oral timing of glottal events. He finds that the glottalization is not strongly tied to the sonorants’ articulation, while the gestural timing of ejectives (the stop and glottal features of the ejective) is very closely tied to the oral articulation.

Bird et al. (2007) studied glottalized sonorants in three languages of the Pacific Northwest: two Northern Interior Salish and one Southern Wakashan. They investigated the gestural timing of glottalization in relation to the sonorants in these

three languages to determine if the sonorant is initially, medially, or finally glottalized, or glottalized throughout. Bird et al. also investigated this in many positions of the syllable, with the syllable, in which the glottalization occurs, pre-stressed, post-stressed, or not near a stressed syllable, and with the syllable in various locations in the word. Controlling for all of these factors, they found that no pattern held across the languages to account for the differences in timing.

Aoki (1970) studied glottalized sonorants in Nez Perce and found that there is often a pause (a glottal stop) when the sonorant is intervocalic which is also marked by a decrease in amplitude (68-69). He also finds that at the ends of words the glottalization is shown with creak. Along with the creak a decrease in pitch is also heard. I find, however, as will be discussed in Section 3.3.2.1, that the pitch is increased in some of the sonorants.

This chapter adds to these studies on glottalized sonorants by including data from Nez Perce. The language has interesting constraints on the location of these segments. They can occur word-medially and word-finally but not word-initially,²³ while Nez Perce ejectives can occur word-initially and word-medially but not word finally. The gestural timing is investigated in both the word-medial and word-final positions. Plain sonorants, which can occur word-initially, medially, and finally, are compared to the glottalized sonorants.

²³ Um finds that glottalized sonorants can be restricted to coda positions (1998: 92).

3.2. Data and methodology

Data for this chapter were gathered during the summers of 2010 and 2011 in Lapwai, Idaho. The word lists used in this study were compiled using Aoki's *Nez Perce Dictionary* (1994), Crook's dissertation (1999), language learning materials (NPLP 2002a, 2002b, 2003, 2004, 2007, 2010a, 2010b, 2010c, 2010d, 2010e, ND; NPLP & Crook ND), and native speakers. Words were chosen from the above texts, examined by native speakers and archaic words were eliminated. Additionally, ungrammatical constructions were corrected or eliminated. Words that were determined to be suitable were compiled into a final word list.

Native speakers were recorded in quiet rooms with a Zoom H4n recorder and an AKG C555L head-mounted microphone with an AKG MPA VL adapter. Speakers recorded the words two or three times²⁴ in either isolation or in a carrier phrase.²⁵

I gathered data for initial, medial and word-final sonorants; however, these conditions will be collapsed for this study. Further study will be needed to analyze any potential variation in these environments.

²⁴ Though carrier phrases are intended to elicit more natural speech I was told after using a carrier phrase, "Héenek'e ____ híce", (translation: 'Say ____ again.') that carrier phrases were in fact not very natural for these speakers, as the words were not being used in a conversation or story.

²⁵ Not all speakers had enough time to repeat the words three times, so to ensure that I collected every word on the word list some speakers only repeated the words twice.

The number of tokens varies for each speaker because tokens were discarded due to background noise, devoiced segments (for the target segments), or if upon analysis one of the aspects of study was not calculable. The numbers of tokens for the sonorants are as follows: FS1 (Female Speaker 1) had 324 tokens, FS2 (Female Speaker 2) had 288 tokens, FS3 (Female Speaker 3) had 154 tokens, MS1 (Male speaker 1) had 115 tokens, and MS2 (Male speaker 2) had 110 tokens. Because this chapter investigates the gestural timing and realization of the glottalization on the sonorants, results for the men and the women are collapsed and discussed together. The total number of tokens used in this study is 991.

All of the data were segmented in Praat and measured using Praat scripts. These scripts provided duration measurements. To determine the gestural timing of the glottalization I visually inspected each segment. Each sonorant was marked based on whether it was phonemically glottalized (based on the *Nez Perce Dictionary* (Aoki 1994)) and whether it was realized as glottalized. If the segment was glottalized, it was categorized by how it was realized: with a pause, a single or a few glottal pulses, or as creak. Additionally, the rate of change for glides was marked as continual change, change at the beginning of the segment or change at the end of the segment.

3.3. Results

This section discusses the realization of glottalization on Nez Perce sonorants, including how often phonemically glottalized sonorants are realized as

plain and vice versa. In general, plain sonorants are less likely to be produced as glottalized sonorants than glottalized sonorants are to be produced as plain. The results are discussed using descriptive statistics.

3.3.1. Plain sonorants

There were a total of 991 sonorants in the study. Of these sonorants, 713 were phonemically plain sonorants and 278 were phonemically glottalized (Figure 38).²⁶

²⁶ Whether or not a sonorant is categorized as phonemically glottalized is based on the *Nez Perce Dictionary* (Aoki 1994).

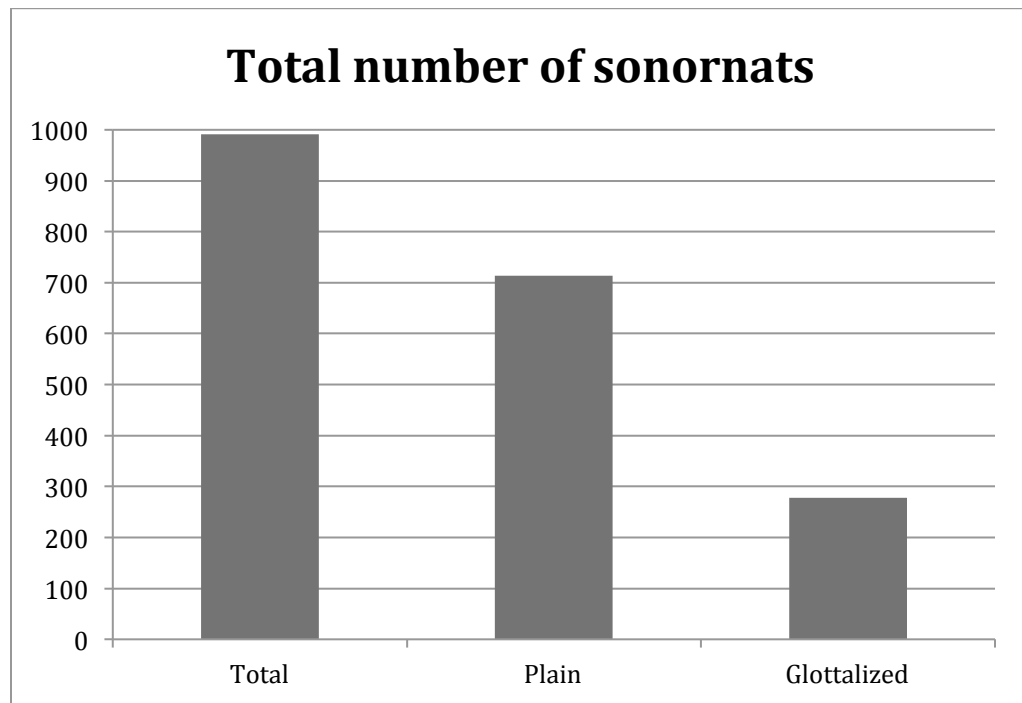


Figure 38 Total number of sonorants including the number of plain and glottalized sonorants.

Phonemically plain sonorants were very rarely realized as glottalized. Of the phonemically plain segments, 681 were realized as plain and only 32, or 4.5%, were realized as glottalized (Figure 39).

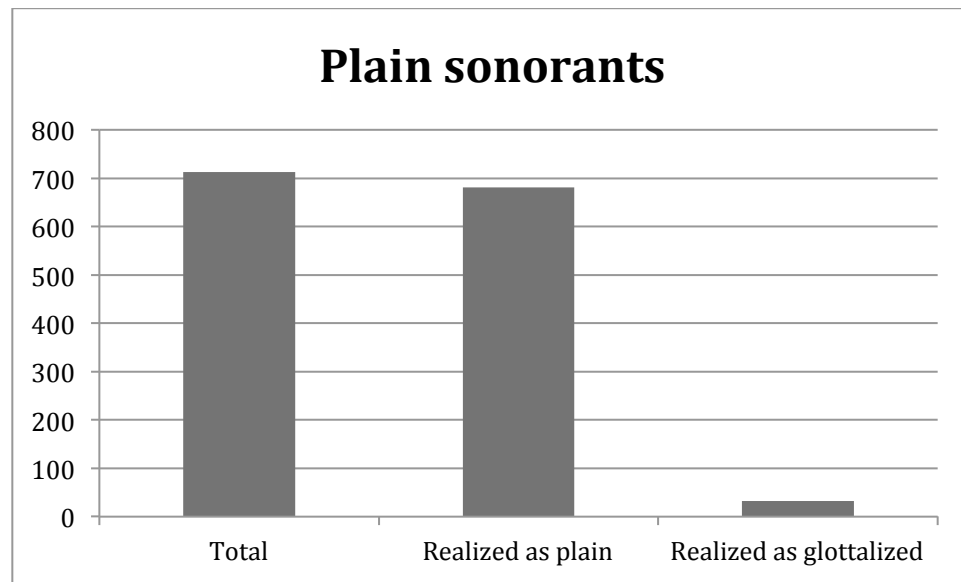


Figure 39 Plain sonorants realized as plain and glottalized.

As mentioned in Section 3.1, Nez Perce has five plain and five glottalized sonorants. These sonorants include the glides /w, j, ɰ, ʃ/. These glides' rates of change show two patterns. The first pattern they show is a continual rate of change or a short steady state followed by a change over a large portion of the glide and the second pattern they show is a steady state with a change at the end of the glide. This first pattern can be seen in Figure 40, which shows a short steady state followed by a change, and the steady state followed by a change at the end of the glide can be seen in Figure 41. Both figures show the same segment, a word-initial [w] spoken by two different speakers.

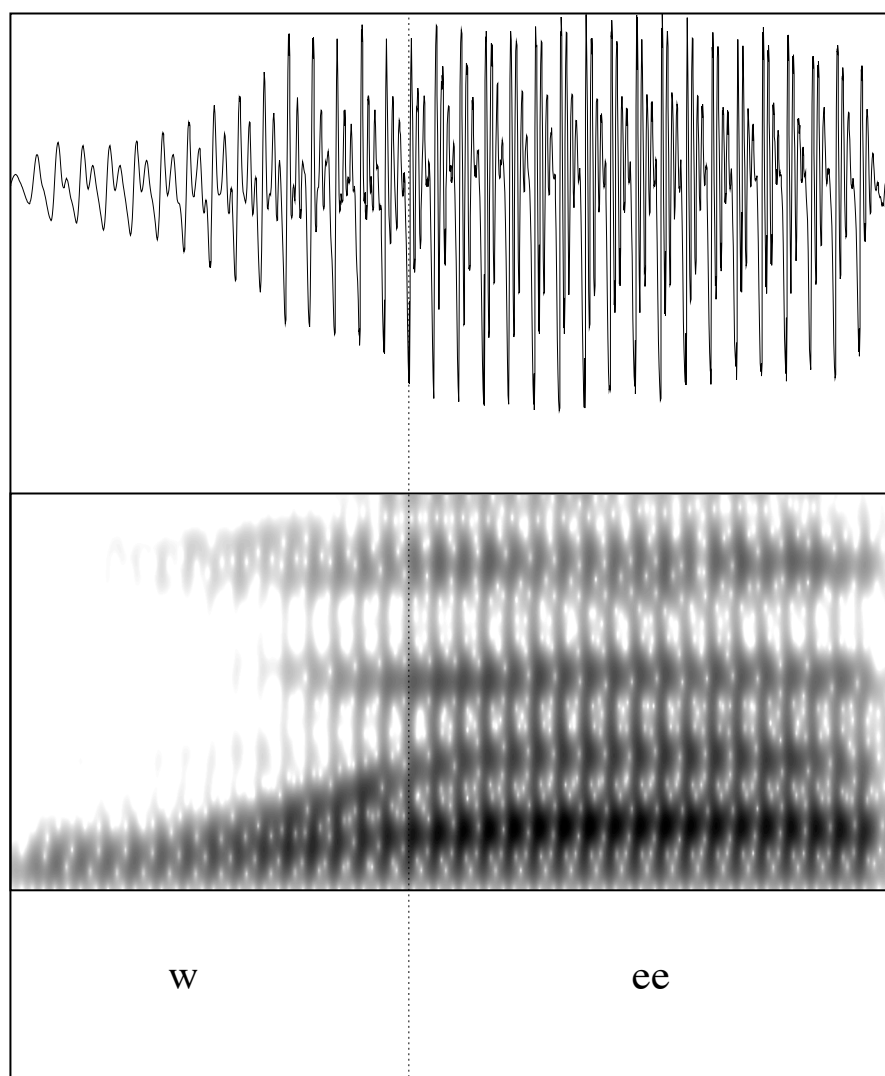


Figure 40 *Weeptes* 'eagle', spoken by FS1, showing a short steady state followed by a change over a large portion of the glide.

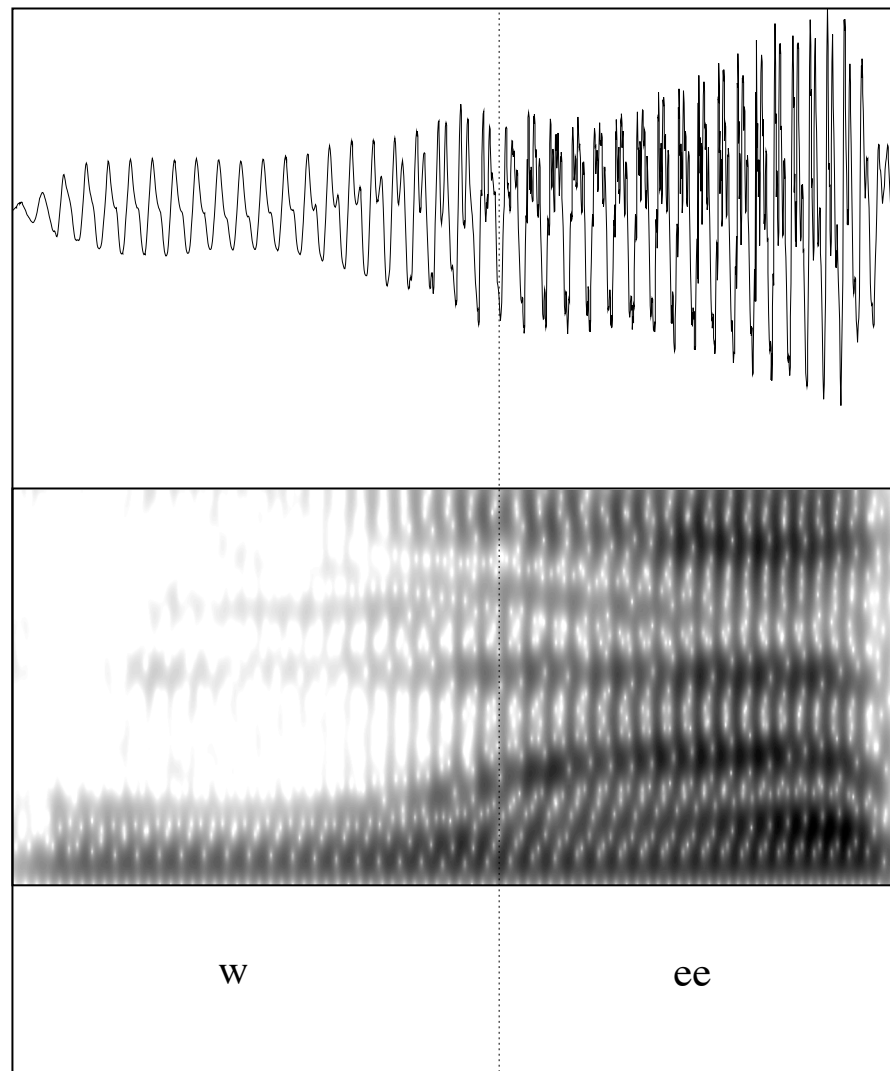


Figure 41 *Weeptes* 'eagle', spoken by FS2, showing steady state followed by a change at the end of the glide.

These two patterns are by far the most common, representing 145 of the 182 glides (about 80%) in the study. Some of the other 37 glides show a steady state

with the glide portion starting closer to the midpoint, or an early glide portion followed by a steady state and then another glide portion near the end.

3.3.2. Glottalized sonorants

In contrast to the plain sonorants, which were generally produced as plain, the glottalized sonorants were realized as glottalized with less regularity. About 18% of the glottalized sonorants (227 of 278) were produced as plain (Figure 42) whereas only 4.5% of the plain were produced as glottalized.

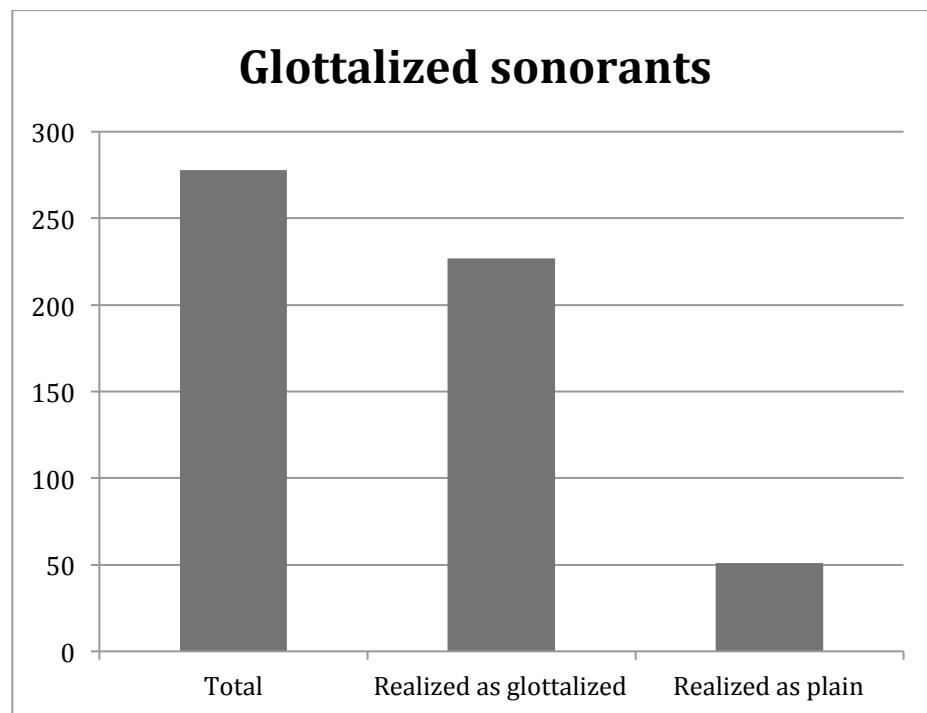


Figure 42 Total number of glottalized sonorants and total number realized as glottalized and as plain.

In addition, the production of the glottalized sonorants varied. They were most often produced with a change in pitch (51.1%, discussed below in Section 3.3.2.1),²⁷ followed by laryngealization or creak (46.6%), and then a complete glottal stop (27.3%).²⁸ This variation can be seen in Figure 43. There is overlap between these groupings because some segments were produced, for example, with laryngealization and a complete glottal stop.

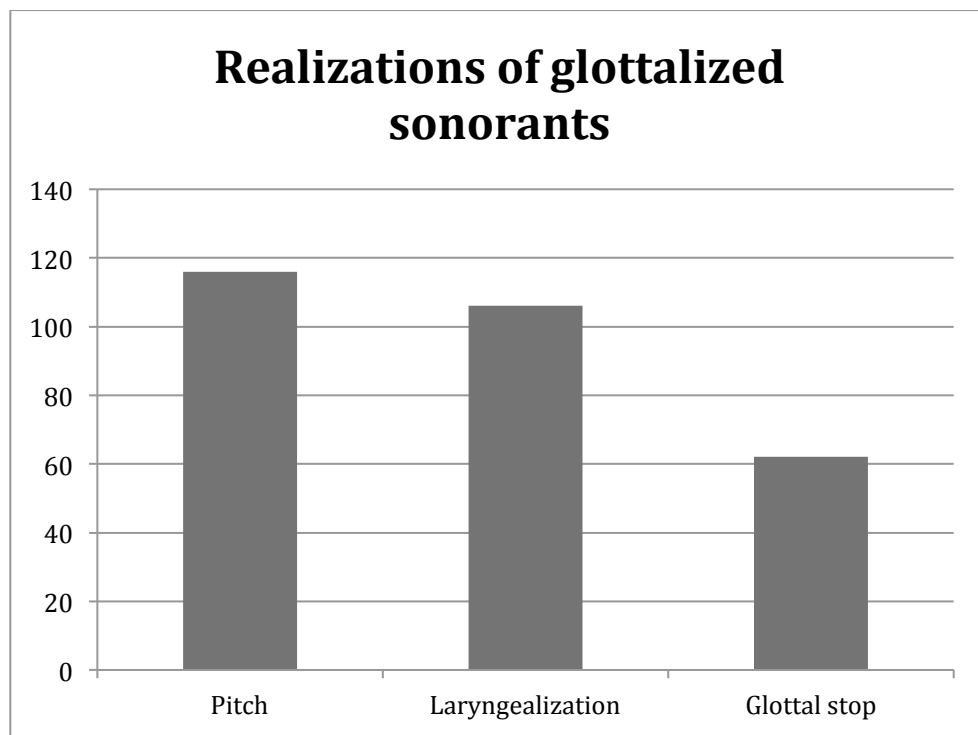


Figure 43 Different realizations of glottalized sonorants.

²⁷ Pitch was controlled for during recording. I maintained the same pitch and intonation every time I asked speakers to repeat the word. This prevented list intonation.

²⁸ Glottalized sonorants produced with a few glottal stops were included in the glottal stop group.

Such variation is not all that uncommon when dealing with glottalized segments (Kingston 1985: 319-352; Ladefoged & Maddieson 1996: 73-77). Pike & Pike (1947) find that the glottal stop in Mazateco, a language of Oaxaca, Mexico, is produced as both a full stop and laryngealization on the surrounding vowels (78-79). Commonly glottal stops are not realized as a complete closure but instead as laryngealization (Ladefoged & Maddieson 1996: 75). This variation is commonly seen in glottalization in other languages.

3.3.2.1. Pitch

The presence of a pitch increase in Nez Perce glottalized sonorants was an unexpected result. Aoki (1970) mentioned that the glottalized sonorants display a “lowering of pitch or frequency of the glottal pulse” (71). I observed while studying Nez Perce that I often did not hear laryngealization, however I perceived the sonorant as glottalized. My first thought was that the orthography was affecting my perception. Upon further analysis, however, I noticed a rise in pitch on the vowel preceding the sonorant for these segments. This change in pitch can be present when there is a glottal stop or modal phonation or both. Not all glottalized sonorants display this pitch change on the preceding vowel; 116 of the 278 phonemic glottalized segments display this pitch change (Figure 43, above).

Figure 44 and Figure 45 show the pitch contours for a plain alveolar and a glottalized bilabial nasal, respectively. Praat does not always correctly track this

pitch, however, it is audible. Further analysis needs to be conducted to fully understand this change in pitch associated with the glottalized sonorants.

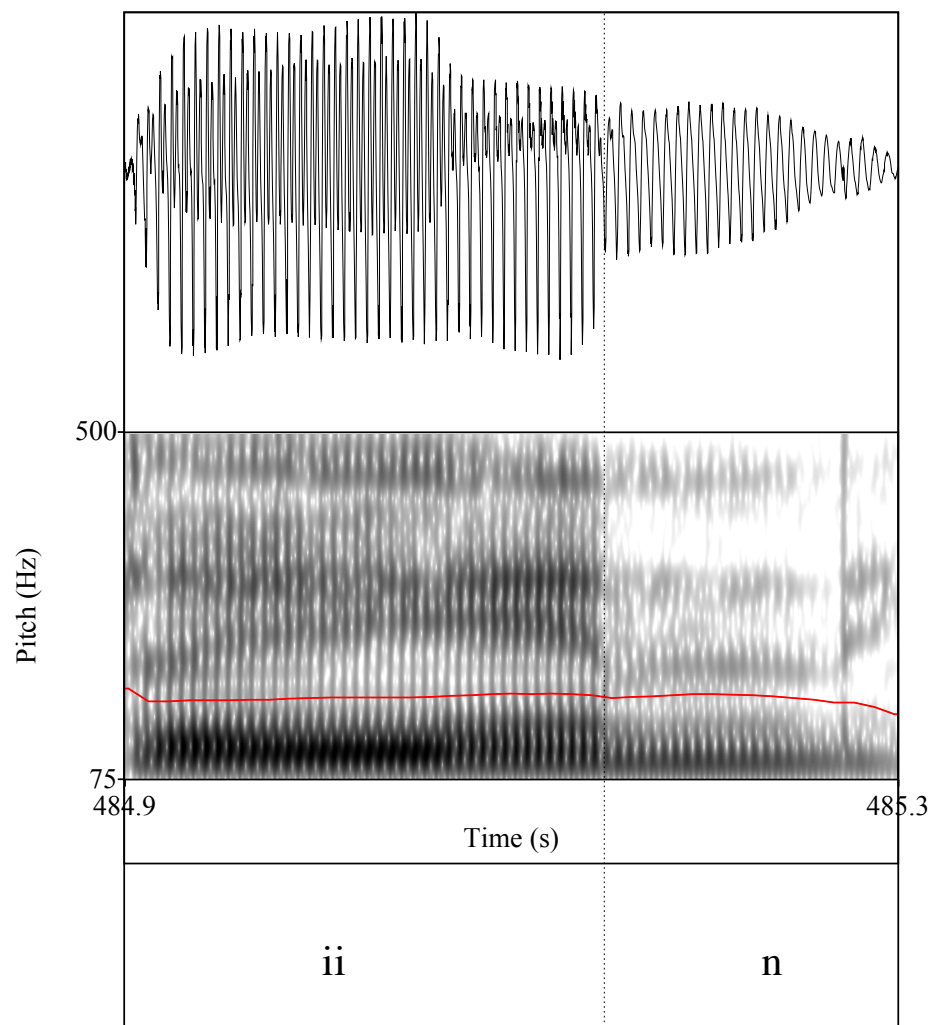


Figure 44 Final two segments in *tasqiin*²⁹ ‘with fat, marbled (of meat)’ spoken by FS1, showing the pitch contour of a word final plain alveolar nasal.

²⁹ IPA transcription [tasq̪iːn] The high front vowel is both nasalized (marked below the vowel) from the word-final alveolar nasal but is also centralized (marked above the vowel) because it follows the uvular stop.

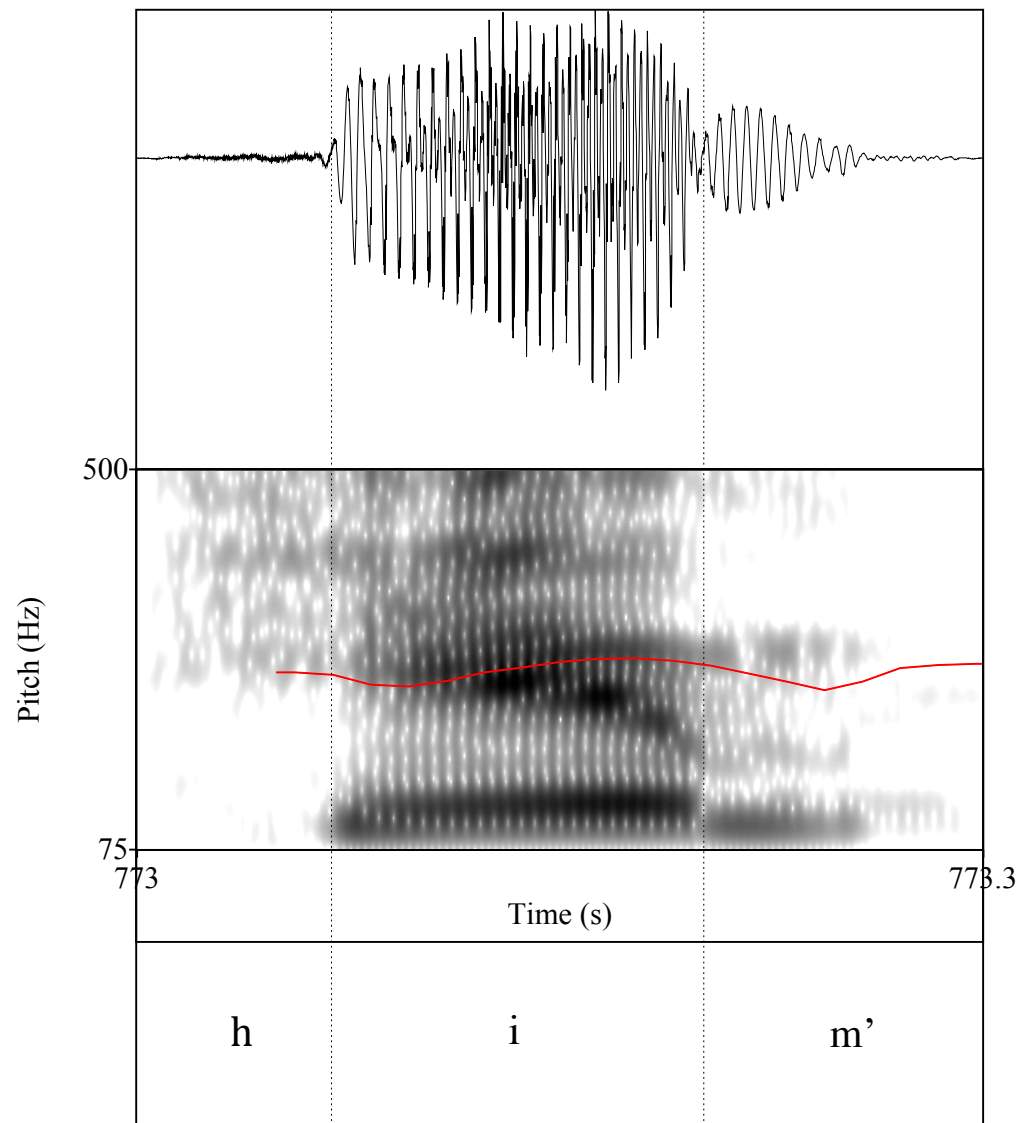


Figure 45 *Him*³⁰ ‘mouth’ spoken by FS3 showing pitch contour for a word-final glottalized bilabial nasal.

³⁰ IPA transcription [hĩm]

This pitch change was heard for some of the plain sonorants as well. I included these segments in the count of plain sonorants realized as glottalized. Of the 32 segments, almost half, or 15, of these segments showed a possible pitch change.

Kingston (2005) discusses the effects of glottalization on pitch. He investigated how some Athabaskan languages developed tone from this pitch difference caused by ejectives on the surrounding segments. Some of the Athabaskan languages developed tone, collapsing the difference between ejectives and plain consonants, while others retained a difference between stem final ejective and plain consonants.

Ejectives affect the f_0 of the surrounding segments (Kingston 1985, 2005), and depending on the language this can be an increase or a decrease in f_0 . Nez Perce shows a decrease in f_0 following ejectives for the women and an increase in f_0 following ejectives for the men (Section 2.3.1). This suggests that speakers are aware of the pitch differences and may utilize it in sonorants as well.

Additionally, Kingston (1985) finds that the secondary phonetic features of ejectives, such as pitch, are more closely tied to the segment than they are for glottalized sonorants. This provides an explanation as to why Nez Perce speakers utilize the secondary phonetic cue of pitch while forgoing the laryngealization.

Beddor (2009) finds that speakers' reinterpretation of phonetic cues can lead to sound change. She studied the shift from vowel-nasal combinations to nasalized

vowels, finding that speakers begin to rely on the anticipatory nasalization in the vowel and eventually delete the nasal.

In the case of Nez Perce it is possible that speakers are retaining the tension in the vocal folds present when producing creak, but this tension is leading to a raised pitch rather than a lowered pitch. Both creak and higher pitch require tension in the vocal folds (Johnson 2003: 138; McCoy 2004: 66). It is possible that rather than retaining the lower pitch present with creak, the speakers are producing a raised pitch instead. Furthermore, Nez Perce is pitch-stress language, meaning that the stressed syllables tend to have a higher pitch than the unstressed syllables.³¹ This lends further evidence suggesting speakers are more attuned to the secondary acoustic cue of pitch change during glottalization. I do not suggest that Nez Perce is developing tone, but I do suggest that speakers are utilizing a secondary phonetic cue of glottalization to assist in production of glottalized sonorants.³²

3.3.2.2. Laryngealization

The second most common realization of glottalized sonorants in Nez Perce is laryngealization or creak on the segment. This is seen in 106 of the 278 tokens

³¹ I observed this while conducting my research.

³² This increased pitch could be a by-product of language loss or it could simply be an example of language change, as is observed in Malagasy (Howe 2013 unpublished manuscript). Howe has noted tone development in the central dialect of Malagasy due to a loss of voicing on fricatives.

(38%) and can co-occur with a full glottal stop. Two examples of laryngealized sonorants can be seen in Figure 46 and Figure 47.

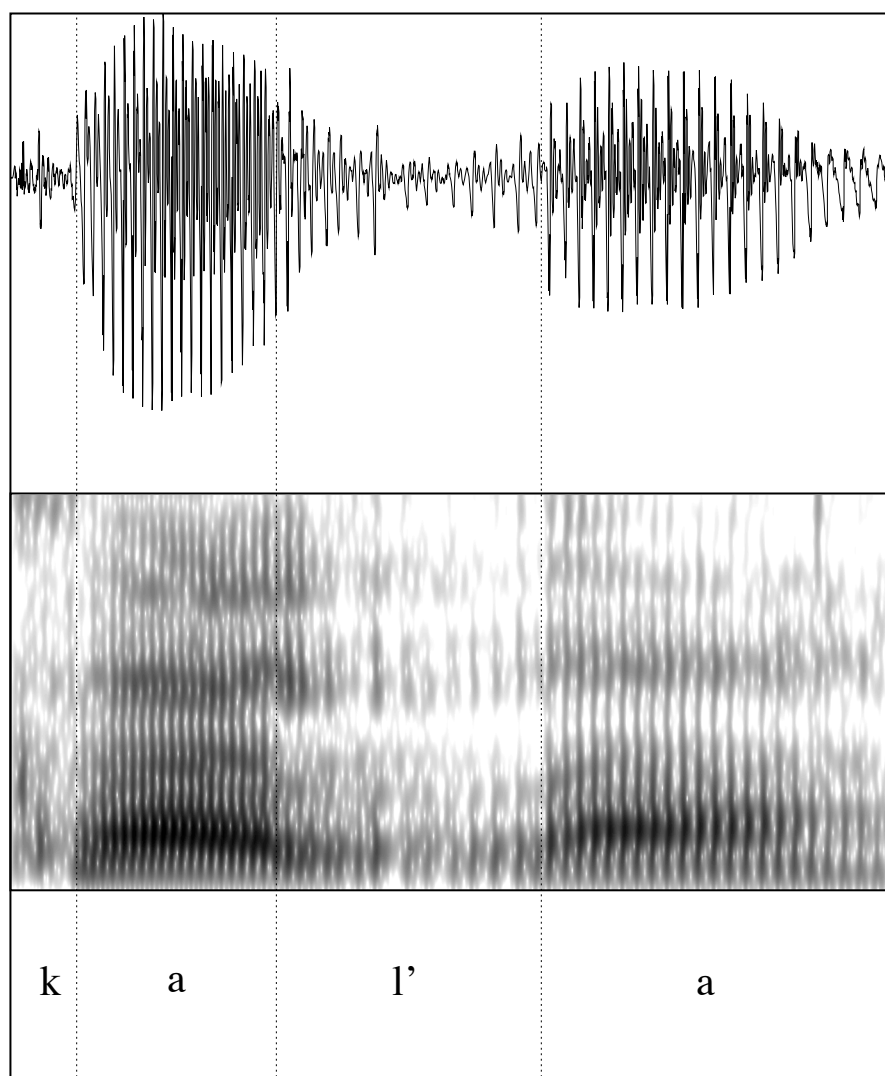


Figure 46 *Kal'a³³* 'just' spoken by FS1 showing the glottalized lateral realized with laryngealization or creak.

³³ IPA transcription [k^hʌ̤a]

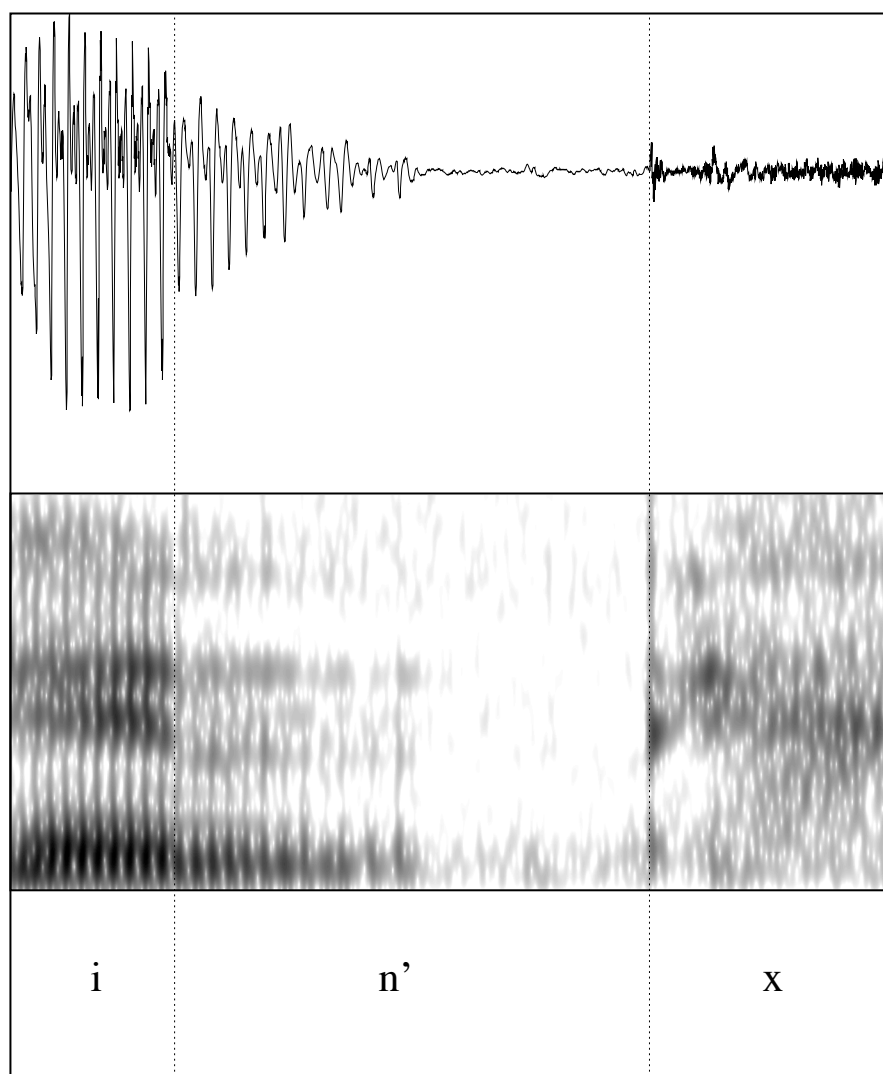


Figure 47 *Tin'xniin*³⁴ 'dead' spoken by FS1 showing the laryngealization on the nasal followed by a stop.

³⁴ IPA transcription [tʰṽṽxnĩ:n]

As mentioned in Section 3.3.2, laryngealization is highly variable. Figure 46 shows an example of laryngealization throughout the entire segment while Figure 47 shows the laryngealization on the first part of the alveolar nasal followed by a full glottal stop.

3.3.2.3. Glottal stop

In addition to the laryngealization and the pitch change, glottalized sonorants can be realized with a full glottal stop, or a few glottal stops.³⁵ An example can be seen in Figure 48.³⁶

³⁵ In this case a few references one to four pulses, usually two or three.

³⁶ This example also shows that glottalized sonorants can be produced with modal phonation. The first phonologically glottalized lateral in the word is produced with modal phonation followed by a glottal stop. The second phonologically glottized lateral in the word is produced with modal phonation and no laryngealization or creak, no pitch change and no glottal stop.

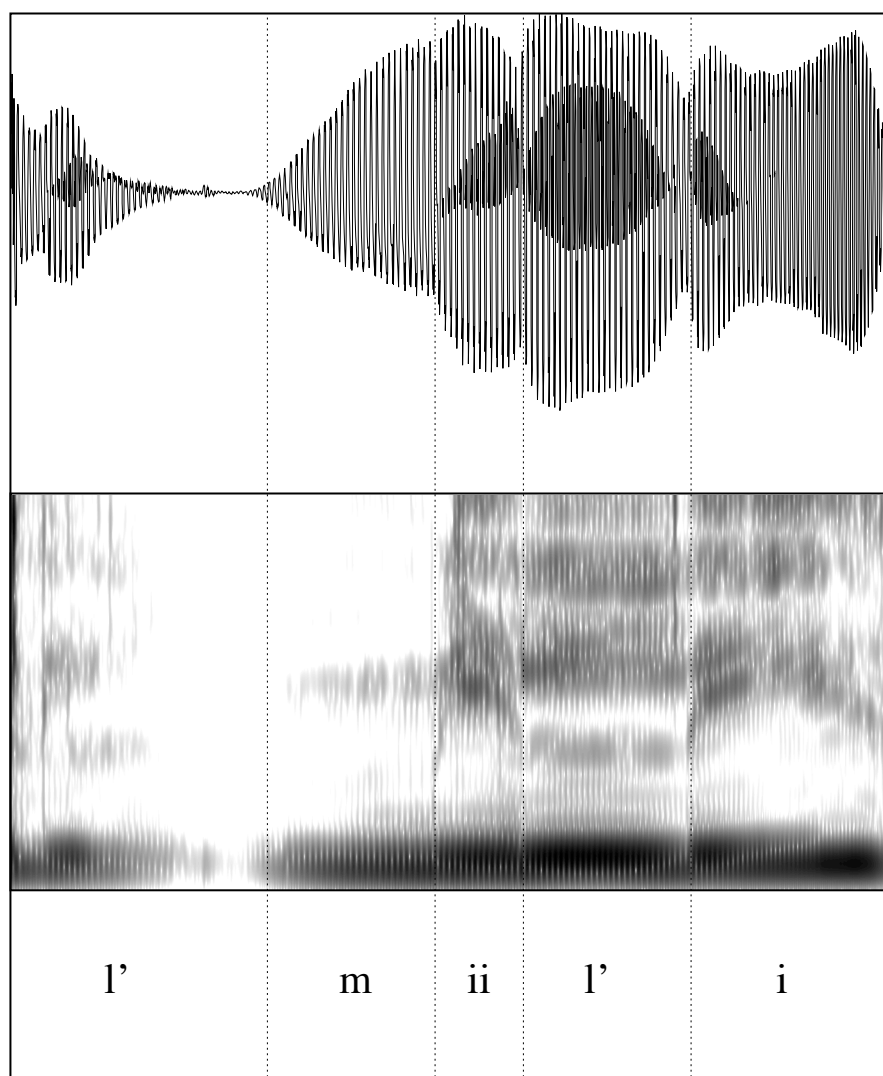


Figure 48 *Himil'miil'ise*³⁷ 'It is pacing' spoken by FS2 showing the glottal stop following the phonologically glottalized lateral.

³⁷ IPA transcription [himilʔmilisə]

I differentiate these examples from laryngealization because the glottal pulses are not as regular as those seen in creaky phonation (see Section 3.3.2.2). Often there are between one and about four glottal pulses in these examples.

The medial duration of the stop is 82.40 ms and the average duration of the glottal stop is 100.54 ms.³⁸ Sometimes this pause was the only indicator of glottalization while other times it occurred along with creak before or after the stop or in both positions. Additionally this glottal stop generally occurred segment-medially or segment-finally.

3.3.3. Duration

Duration was also measured for all sonorants. These results were separated by speaker. Results showed a tendency for glottalized sonorants to be slightly longer than the plain sonorants, though this did not hold for all speakers or for all plain and glottalized pairs. Figure 49 shows these measurements for FS1. Measurements for the other speakers can be found in Appendix B.

³⁸ There were two outliers excluded for this measurement. Including these two longer stops the average duration is 122.23 milliseconds and the median duration is 83.05 milliseconds.

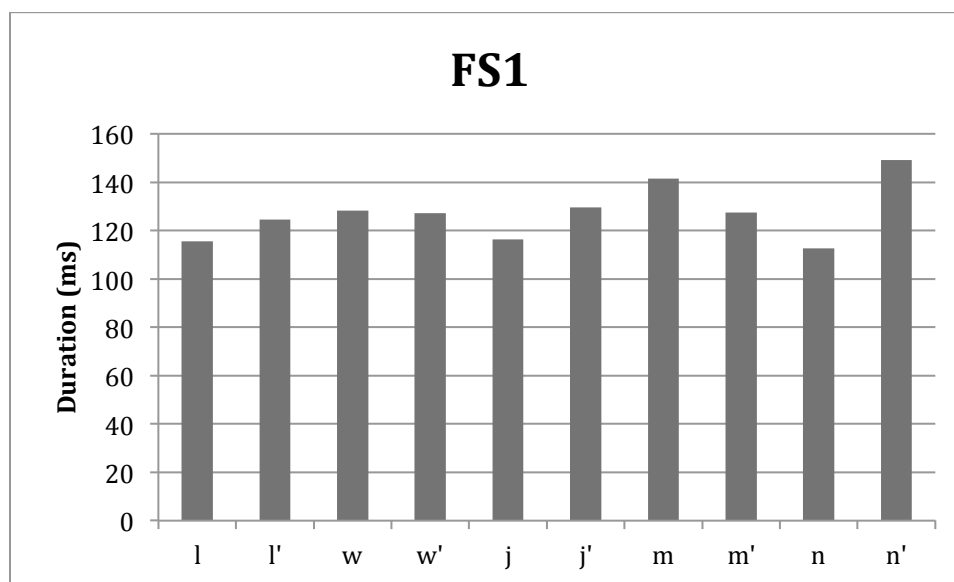


Figure 49 Duration measurements for all sonorants for FS1.

As Figure 49 shows, many of the glottalized sonorants are longer than the plain sonorants, however as can be seen in the labio-velars and the bilabials this is not the case. These measurements are collapsed across environment.

Upon investigating the durational differences between the word-medial location and collapsed across all of the environments, the word-medial position still displays the longer duration. This can be seen in Figure 50.

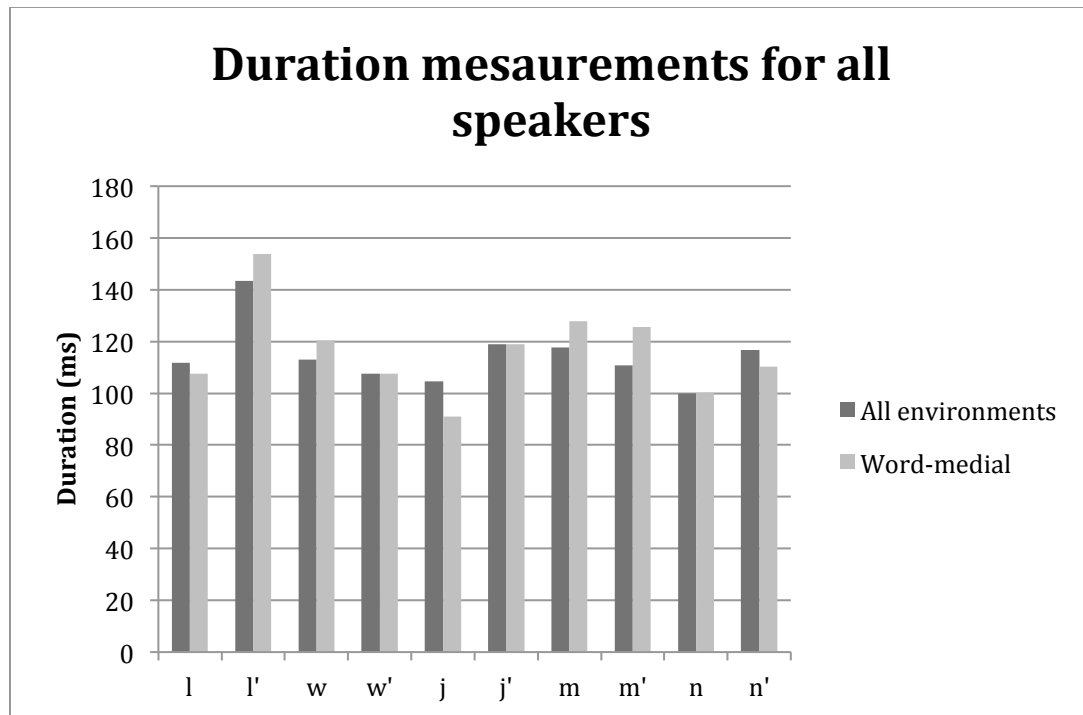


Figure 50 Durational measurements collapsed across all environments and the word-medial position for all speakers.

This data suggests that the glottalized sonorants are generally longer than the plain sonorants. These measurements include the glottalization realized with a glottal stop, which could increase the durational measurements in comparison to the plain sonorants.

3.4. Summary

This chapter discussed Nez Perce plain and glottalized sonorants and covered the varying realizations of these segments. Glottalization in Nez Perce was realized with pitch changes, laryngealization, a glottal stop, or a combination of these features, the most common of which was a raised pitch. All of these features need to be further studied to fully understand how they interrelate and function in Nez Perce sonorants.

Chapter 4

Vowels

Nez Perce vowels have often been studied in phonology because of the unusual five vowel inventory; however all of this research has been in relation to vowel harmony in the language, as discussed in the following chapter. To date, there have been no acoustic studies of the Nez Perce vowels. This chapter will address that, by providing an acoustic analysis of the Nez Perce vowels, and comparing these results to other vowels systems in the world's languages. I also discuss Nez Perce vowels in relation to the principle of maximal contrast and how the analysis of the Nez Perce vowel system can add to the principle of maximal contrast.

4.1. Background

There are five monophthongal vowel qualities with phonemic length in the Nez Perce inventory. In addition there are seven diphthongal vowel qualities with phonemic length. These vowels are outlined in Figure 51 and Figure 52.

<u>Monophthongs</u>						
	<u>Short</u>			<u>Long</u>		
	<u>Front</u>	<u>Central</u>	<u>Back</u>	<u>Front</u>	<u>Central</u>	<u>Back</u>
High	i		u	i:		u:
Mid			o			o:
Low	æ	a		æ:	a:	

Figure 51 Nez Perce monophthongs (Crook 1999: 21)

<u>Diphthongs</u>						
	<u>Short</u>			<u>Long</u>		
	<u>Front</u>	<u>Central</u>	<u>Back</u>	<u>Front</u>	<u>Central</u>	<u>Back</u>
	iw	aw	uy	i:w	a:w	u:y
	æw	ay	oy	æ:w	a:y	o:y
	æy			æ:y		

Figure 52 Nez Perce diphthongs listed by the frontness and backness of the nucleus.

Maddieson (1984) and Schwartz, Boë, Vallée & Abry (1997) use UPSID³⁹ to describe generalizations about vowel systems of the world’s languages. Their studies include Nez Perce, which has a five-vowel system, the most common number

³⁹ Maddieson uses UPSID, the UCLA Phonological Segment Inventory Database, which is a collection of 317 languages in his 1984 book, *Patterns of Sounds*, to describe generalizations about consonant inventories of the world’s languages, including Nez Perce.

of vowels per language.⁴⁰ According to their research, the Nez Perce vowel system is unusual for a five-vowel system because there is no mid front vowel, but instead, a low front vowel, /i æ a o u/. In addition, it does not follow the basic triangular vowel space, Figure 53, commonly seen in the majority of languages (Maddieson 1984: 136; Schwarts, Boë, Vallée & Abry 1997: 251).

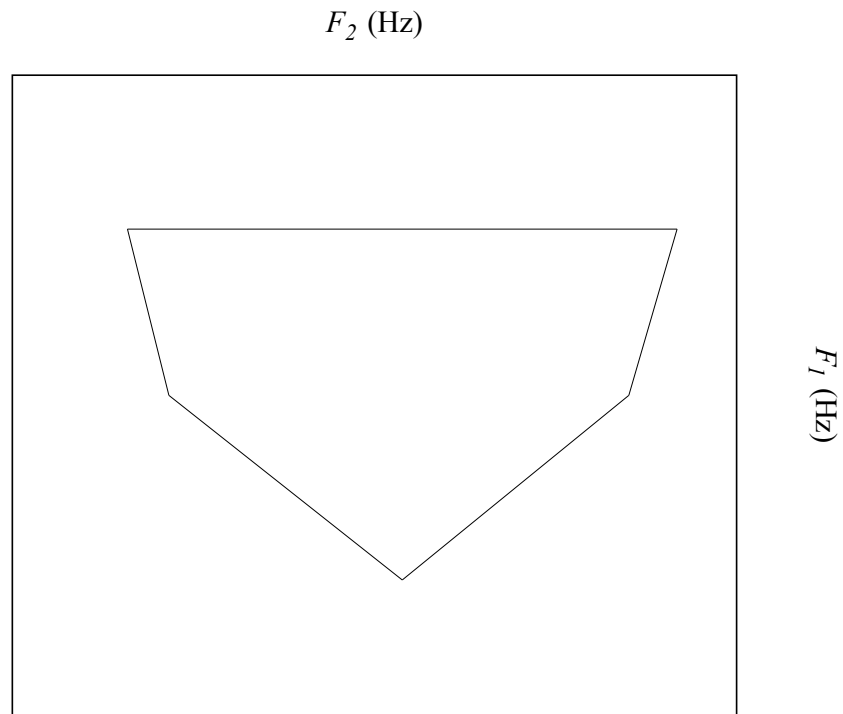


Figure 53 Basic five-vowel triangular vowel space.

⁴⁰ The Nez Perce vowel inventory described by Maddieson's (1984) book differs slightly from other analyses as well as the analysis, which I will be using in this dissertation. Maddieson writes that the Nez Perce [o] is an [ɔ].

This triangular pattern seen in Figure 53 follows the theory of maximal dispersion or principle of maximal contrast, which states that vowels will be equally dispersed in a vowel space (Liljencrants & Lindblom 1972). In addition, the hyperspace effect (Johnson, Flemming, & Wright 1993), which is similar to the principle of maximal dispersion or contrast, states that speakers perceive the phonetic segments they hear as hyperarticulated, or more peripheral in the vowel space.

Most languages have at least three vowels, /i, a, u/, supporting the theory of maximal dispersion, though there are some Caucasian languages, Kabardian for example, which are said to have less than three vowels, because their surface representations are predictable based on context (Colarusso 1992: 18). The basic three-vowel system shows that languages like to have the vowels fairly evenly dispersed between the front and back of the mouth and in height.

Maddieson finds that this triangular pattern is commonly seen in languages regardless of the number of vowels in the inventory, though the five-vowel system is the most commonly seen vowel system. He finds that 209 of the 317 languages in UPSID, have the five-vowel system /i, ε, a, ɔ, u/. Additionally, less than five percent of the languages with a five-vowel system use a configuration other than the triangular pattern. It is uncommon for a language to have a gap, such as the lack of the mid front vowel in Nez Perce and only 43 of the 317 languages, or 13.6%, have a gap in their inventory (Maddieson 1984: 136).

If a language does have a gap in its vowel inventory, this missing vowel is least likely to be the high front vowel, /i/, or the low central vowel, /a/, meaning the high back vowel is more likely to be missing (Maddieson 1984: 142). Maddieson finds that in general for a five-vowel system the hierarchy of vowels is {i, a}>{e, o}>u (142). Nez Perce, however is lacking /e/ and does not follow this hierarchy though Rigsby & Silverstein (1969) suggested that the low front vowel /æ/ developed from a mid front vowel, /e/. (For a complete discussion on the development of the vowel system see Section 5.1.)

A type of gap Maddieson discusses is a gap caused by a vowel of unexpected height (1984: 147-148). This is the type of gap seen in Nez Perce: one of the front vowels is not mid, as would be expected, but low. Maddieson finds that in the 317 languages there are only three languages with the same gap: Nez Perce, Taishan and Ket. All of these languages use /æ/ in place of /e/ or /ɛ/ (Maddieson 1984: 148). Taishan has a similar five-vowel system, while Ket employs more vowels.⁴¹

As stated above, however, Nez Perce vowels have not been instrumentally studied and plotted to determine the acoustic vowel space. All previous work has been done by ear, not instrumentally. As will be discussed in section 5.5, scholars have been debating about Nez Perce vowel harmony for many years, using different

⁴¹ Georg (2007) does not use /æ/ in his phonological analysis of Ket, but instead uses /e/. He does recognize that there are some words with /æ/ but there are not many. In addition they occur more often in a northern dialect. Georg writes that he decided to use the phonological representations /e/ and /a/ because they were the best choices for the few instances of /æ/ that he found.

IPA symbols for the same vowels. An acoustic study of the Nez Perce vowel system will help lay the ground work for understanding the unique Nez Perce vowel system and vowel harmony. It will also provide additional information for the theory of maximal dispersion and the hyperspace effect. While the Nez Perce vowels do not appear to follow the theory of maximal dispersion, my analysis of Nez Perce suggests that they are indeed maximally dispersed but not in the traditional way.

4.2. Data and methodology

Monophthongal and diphthongal vowels were measured at the onset of voicing. Only the voiced sections of the vowels were measured.⁴² The same Praat script was used to measure all vowels, both monophthongs and diphthongs. The script measured vowels in twelve places with the first measurement being the onset of the vowel and the last measurement being the end of the vowel. The sixth measurement (middle of the vowel) was used for monophthongs and the fourth and ninth measurements (one-third and two-thirds into the vowel) were used for the diphthongs. All data was checked for outliers and was plotted using the Praat picture window.

The data for the monophthongs for the women were gathered in Summer 2009, while I conducted the study for plain obstruents (stops and affricate) and

⁴² Some speakers devoiced the initial or final sections of the vowels.

ejectives. During that study I gathered both plain obstruents and ejectives next to every vowel, both long and short, word initially and word medially. All of these vowels were used in this section. The data for the men was gathered in the summers of 2010 and 2011. The number of tokens for the monophthongs are as follows: FS1 (Female Speaker 1) had 532 tokens, FS2 (Female Speaker 2) had 473 tokens, FS3 (Female Speaker 3) had 504 tokens, MS1 (Male speaker 1) had 360 tokens, and MS2 (Male speaker 2) had 265 tokens.

The data for diphthongs were gathered during the summers of 2009, 2010 and 2011. The number of tokens for the diphthongs are as follows: FS1 had 139 tokens, FS2 had 111 tokens, FS3 had 92 tokens, MS1 had 96 tokens, and MS2 had 49 tokens.

4.3. Results

The following sections outline the results for the monophthongs, diphthongs, vowel length, phonation types and coarticulation, and unstressed vowels. Vowel plots are provided and vowel dispersion is also discussed.

4.3.1. Monophthongs

Nez Perce has five monophthongal vowels with phonemic length seen in Figure 54 (FS2) and Figure 55 (MS2). (For vowel plots of the other three speakers see Appendix C.) Length will be discussed in this section for the purpose of vowel

qualities and vowel disbursement, though a discussion about the phonemic length will be in Section 4.3.3.

All long monophthongs are peripheral to the short vowels. [æ] and [æ:] are raised from the canonical low position, though [æ] is higher than [æ:]. [i] and [i:] as well as [a] and [a:] show the largest difference between the long and short variants of the vowel. The [a:] is backed and slightly lower in comparison to [a] while [i:] is raised and fronted in comparison to [i]. [i] is in fact produced more similarly to [ɪ] than [i]. The vowel spaces for [u] and [u:] are quite similar and mostly overlap. [u] is slightly fronted in comparison to [u:]. For FS2 [o] is front in comparison to [o:], and [o:] is more tightly clustered than [o]. For MS2 [o] and [o:] overlap.

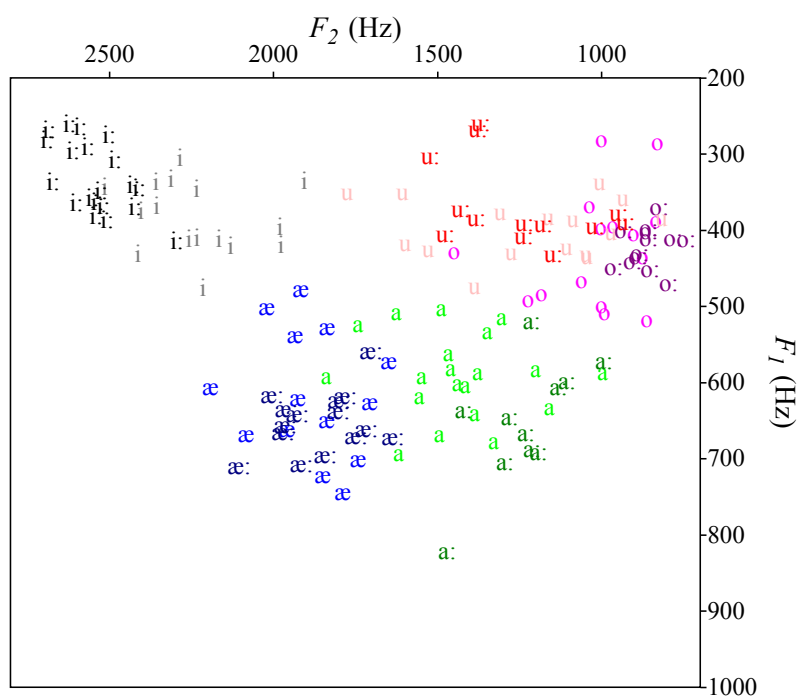


Figure 54 FS2 long and short monophthongs.

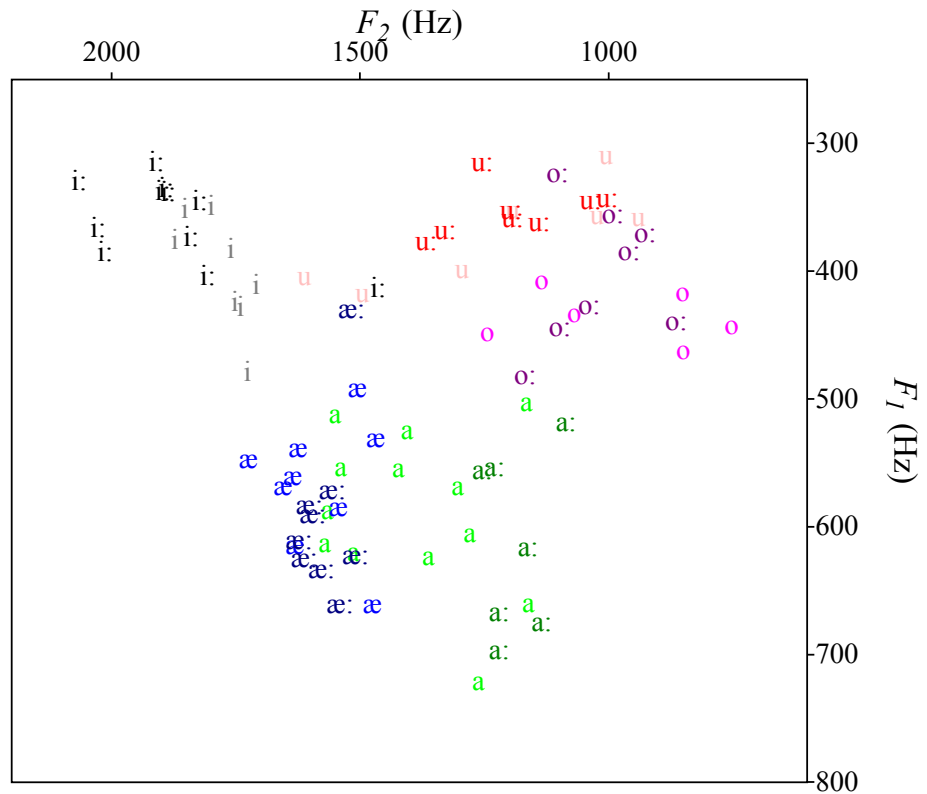


Figure 55 MS2 long and short monophthongs.

[u], [u:], [o] and [o:] have a larger horizontal (F_2) space than the other vowels. The low vowels are about the same height though the [a] and [a:] are slightly lower for MS2 than for FS2. [æ] and [æ:] occur in a narrower second formant area for MS2 than for FS2. FS2 also has a larger vertical (F_1) space for [o] and [o:] than MS2.

The canonical idea of the principle of maximal contrast for a five-vowel system is to have a high front vowel /i/, mid front vowel /e/, low vowel /a/, mid back vowel /o/, and finally a high back vowel /u/. These vowels form a triangular shaped vowel system seen in Figure 56.

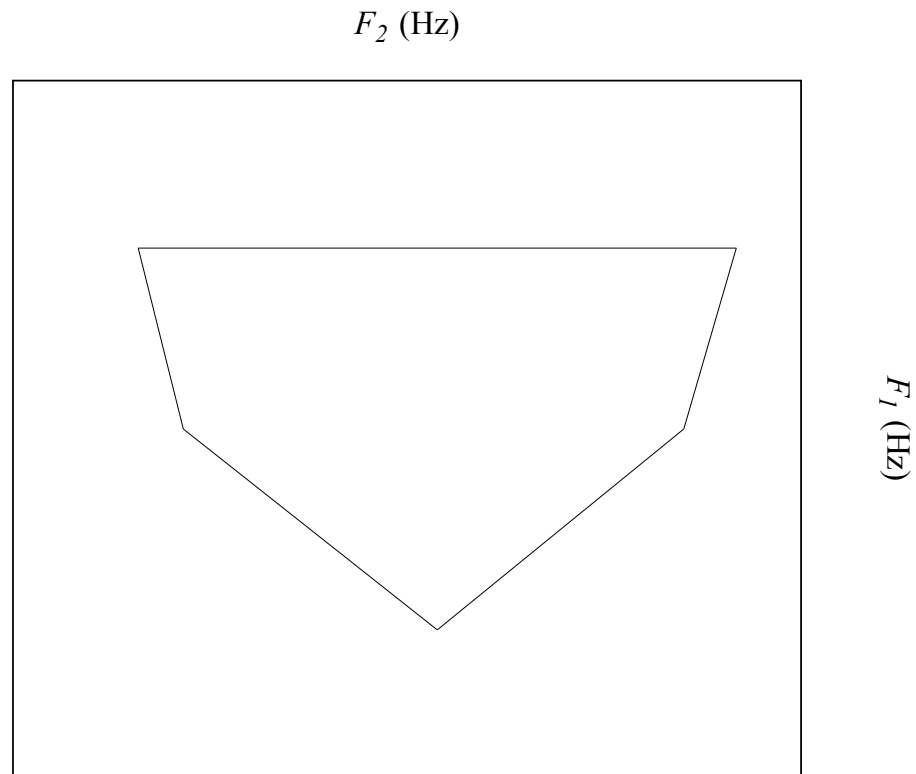


Figure 56 Vowel space outline for the canonical five-vowel system. Repeated for the reader's convenience.

If we consider the outline of the Nez Perce vowels as seen in Figure 57, the vowels form a similar triangular shape to the canonical five-vowel system, it is just turned about 90 degrees to the left.

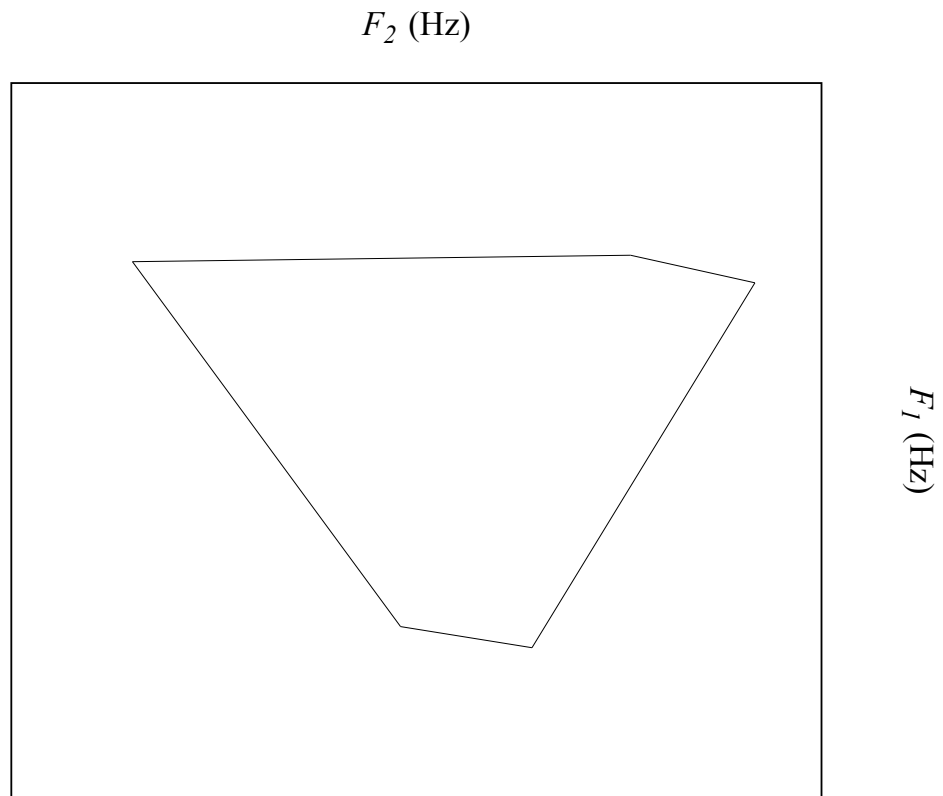


Figure 57 Vowel space outline for Nez Perce vowels.

The data in this chapter shows that though the Nez Perce vowels appear to violate the principle of maximal contrast, upon further analysis the vowels are spread in a manner similar to those of the canonical five-vowel system; there is a triangular shape but it is turned. Other languages previously analyzed as having a gap or missing vowel(s) may really follow the principle of maximal contrast, but not in the expected manner.

4.3.2. Diphthongs

In addition to the monophthongs in Nez Perce there are seven diphthongal qualities with phonemic length. (Length will be discussed in Section 4.3.3.)

Maddieson (1984) claims that there are very few languages with true diphthongs and does not consider the diphthongs in Nez Perce to be true diphthongs. He writes “[a] phonetic diphthong might have one of 3 phonological interpretations: (1) as a phonemic unit, (2) as a vowel and as a consonant in sequence (in either order), or (3) as two vowels in sequence” (161). He also considers the distributional patterns of the monophthongal vowels in comparison to the diphthongal vowels to determine if they are diphthongs by his definition.

In contrast to Maddieson’s analysis of Nez Perce without diphthongs, Crook (1999: 25) discusses diphthongs in his review of the Nez Perce phoneme inventory. In addition, I find no reason in my own research to assume that Nez Perce does not have diphthongs. While I have conducted no rigorous research determining the distribution of Nez Perce diphthongs in relation to the monophthongs, I would claim that they occur in similar environments and function similarly. I found some instances where I believe speakers produce diphthongs differently from vowel-glide combinations. This evidence is based on syllabification, shown by the IPA symbol [.] for syllable boundary. Two such examples are *cuuy’em* and *hipstuuy’*. *cuuy’em* ‘fish’ is sometimes said with the glottalized palatal in the second syllable rather than the first [tsu: j̥ẽm]. It can also be produced as a diphthong with the glide resyllabified on the second syllable [tsu: j̥ẽm]. On the other hand, in *hipstuuy’* ‘enough’ the final [u: j̥]

is all one unit, [hɪp.stuːʃ]. More research is needed to fully understand effects of syllabification on the realization of the diphthongs versus vowel-glide combinations.

The following two plots, Figure 58 (FS2) and Figure 59 (MS2), show the long and short diphthongs for FS2 and MS2. (For vowel plots of the other three speakers see Appendix D.) I have included some unstressed vowels to have examples of all vowel types, though upon analysis they appear to be reduced. Some of these reduced diphthongs can be seen in the following plots with the nucleus of the diphthong in the space of a schwa. The dotted lines show the trajectories for the short diphthongs and the solid lines show the trajectories for the long diphthongs.

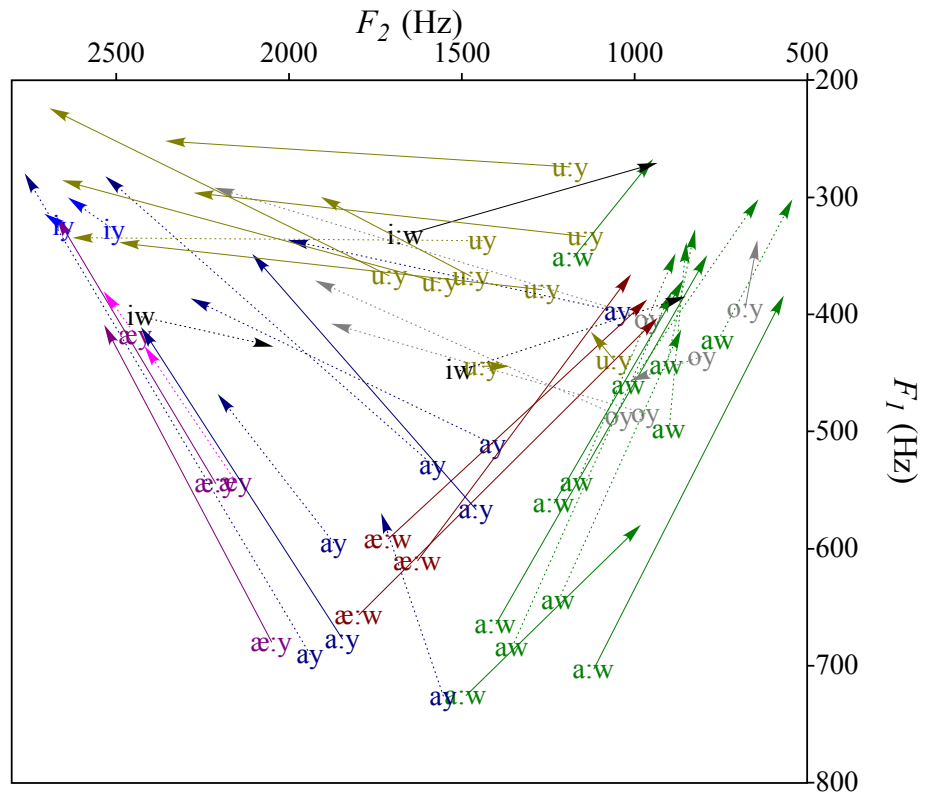


Figure 58 Diphthongs for FS2, both long and short.

As would be expected all diphthongs with the [w] off glide have trajectories toward the back of the mouth and the diphthongs with the [y] off glide have trajectories pointing toward the front of the mouth.⁴³ In general the diphthongs with a long nucleus are more peripheral than those with a short nucleus.

⁴³ The diphthongs [o:y] for FS2 does not follow this pattern. It was the only example I had of the diphthong and included it to be as comprehensive as possible. It is most likely an unstressed token.

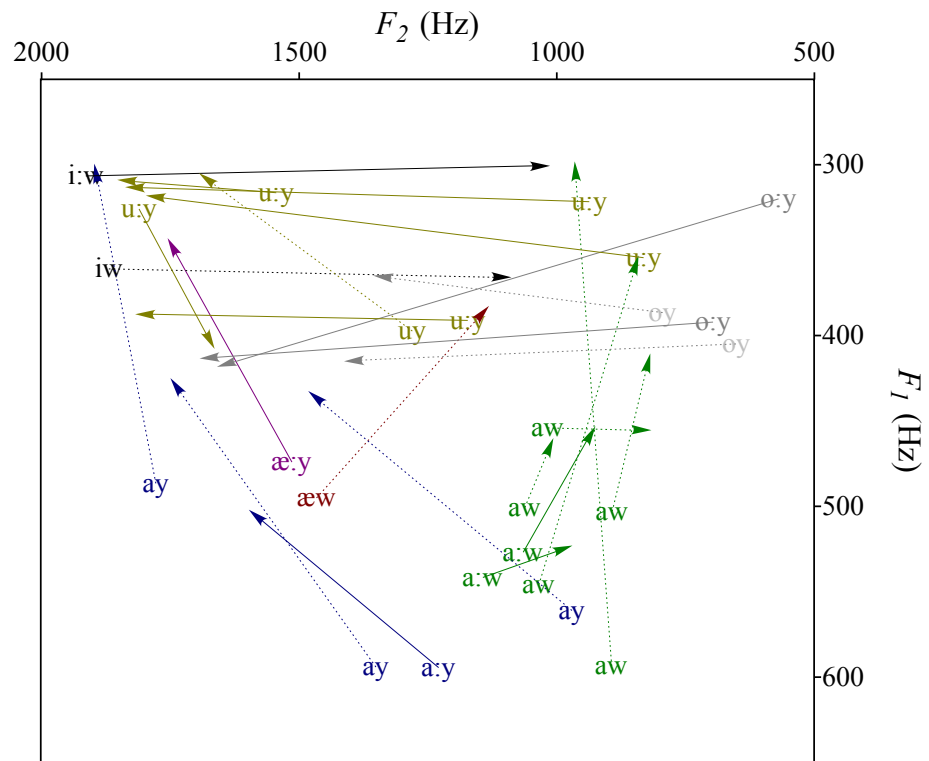


Figure 59 Diphthongs for MS2, both long and short.

The [æ] in /æy/ is raised and is produced more like an [ɛ]. In addition the [a] in /ay/ is also fronted and raised. Crook (1999: 26) also noted this variation in his discussion on Nez Perce diphthongs and said that this affect on the nucleus by the off glide is not as strong with long diphthongs. The [a] in /aw/ is also affected by the off glide. The [a] is raised and backed and again the long diphthong is peripheral to the short vowels. [u] in /uy/ is also fronted in the diphthong.

The same analysis should be conducted with all stressed diphthongs. I believe that I conducted a fairly rigorous examination of the Aoki's (1994)

dictionary to find the examples used in this study. Use of conversational data could yield more stressed tokens.

4.3.3. Length

Nez Perce vowels display phonemic length in both monophthongs and diphthongs. Two examples showing phonemic length can be seen in Example 1 and Example 2. (a) shows the short vowel, while (b) shows the long vowels.

1 (a) méqe'	(b) méeqe'
[mæqæʔ]	[mæ:qæʔ]
'maternal uncle'	'snow'
2 (a) 'ató'sa	(b) 'aató'sa
[ʔatóʔsa]	[ʔà:tóʔsa]
'I go out to see mine'	'I go out to see'

(Examples from Crook 1999: 22)

Maddieson (1984) and Schwartz, Boë, Vallée & Abry (1997) treat long vowels as a secondary system to short vowels because they generally share the same vowel quality. There are some languages where the long and short vowels differ in quality, however, the difference in quality is predictable based on length and there is only one phoneme for each long and short vowel pair.

The durational differences between the long and short monophthongs are very strong while the durational differences between the long and short diphthongs are not as clear. Table 3 shows the durational averages of the long and short

monophthongs for all five speakers while Table 4 shows the durational averages for the long and short diphthongs for all five speakers. FS2 and FS3 show about a 40ms difference between the long and short diphthongs, FS1 only shows and 14ms difference, MS2 only shows a 7ms difference and MS1 shows a 23ms difference. FS2 shows a 49ms difference between the long and short monophthongs, which is close to the difference she shows for the diphthongs. The long monophthongs are twice the length of the short ones for FS1 and more than twice as long for FS3. MS1 displays a 73ms difference and MS2 shows a 45ms difference between the monophthongs, much larger than the differences for the diphthongs.

Table 3 Average duration in milliseconds for the long and short monophthongs for all five speakers.

	FS1	FS2	FS3	MS1	MS2
Short Monophthongs	90ms	89ms	97ms	152ms	108ms
Long Monophthongs	189ms	138ms	214ms	225ms	153ms

Table 4 Average duration in milliseconds for the long and short diphthongs for all five speakers.

	FS1	FS2	FS3	MS1	MS2
Short Diphthongs	251ms	179ms	196ms	350ms	230ms
Long Diphthongs	265ms	219ms	237ms	373ms	237ms

Because the differences in duration between the long and short diphthongs are not as strong as those for the longs and short monophthongs, the long and short diphthongs may be losing phonemic status. Some speakers show a stronger distinction in the durational differences, which indicates that it is a phonemic feature in the language. Some speakers, however, do not show the strong difference between the long and short diphthongs suggesting that it may not be phonemic for those speakers. It may be that durational differences for diphthongs in Nez Perce are smaller than for monophthongs.

The following plots, Figure 60 (FS1) and Figure 61 (MS2), show the averages for the Nez Perce monophthongs, both long and short. (For averages of other speakers see Appendix E.) Unaveraged plots can be found in the preceding Sections 4.3 and 4.3.2, Appendix C, and Appendix D. As is common cross-linguistically, the long vowels are more peripheral to the short vowels. The variation in quality can also be seen in the following plots. The long vowels are more peripheral to the short

vowels. The long and short difference is most clearly seen in the high front vowel /i/, and to a lesser extent in /a/.

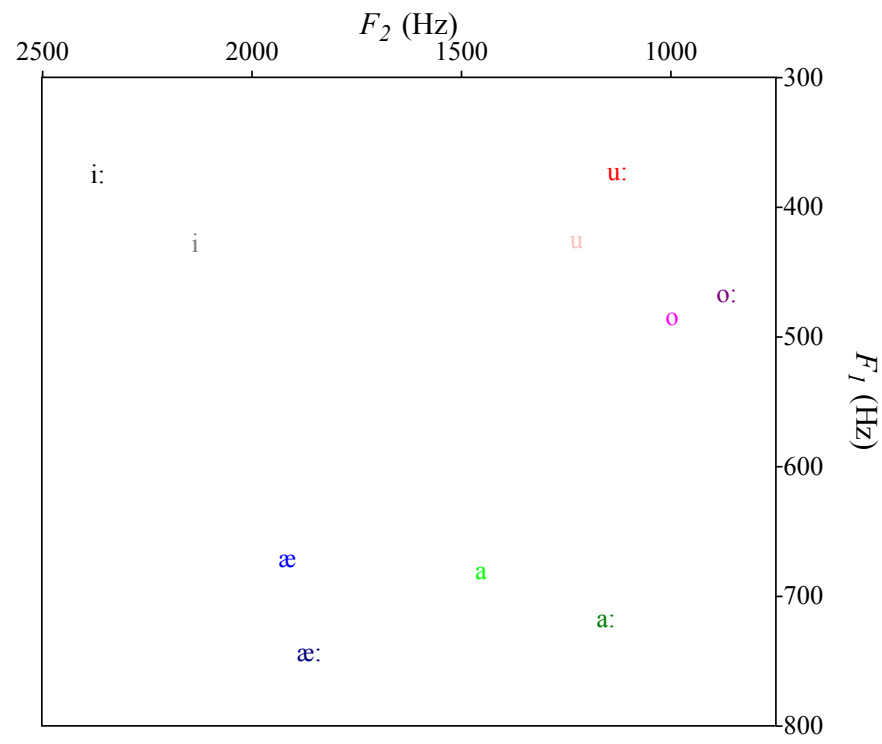


Figure 60 Averages for the monophthongs for FS1.

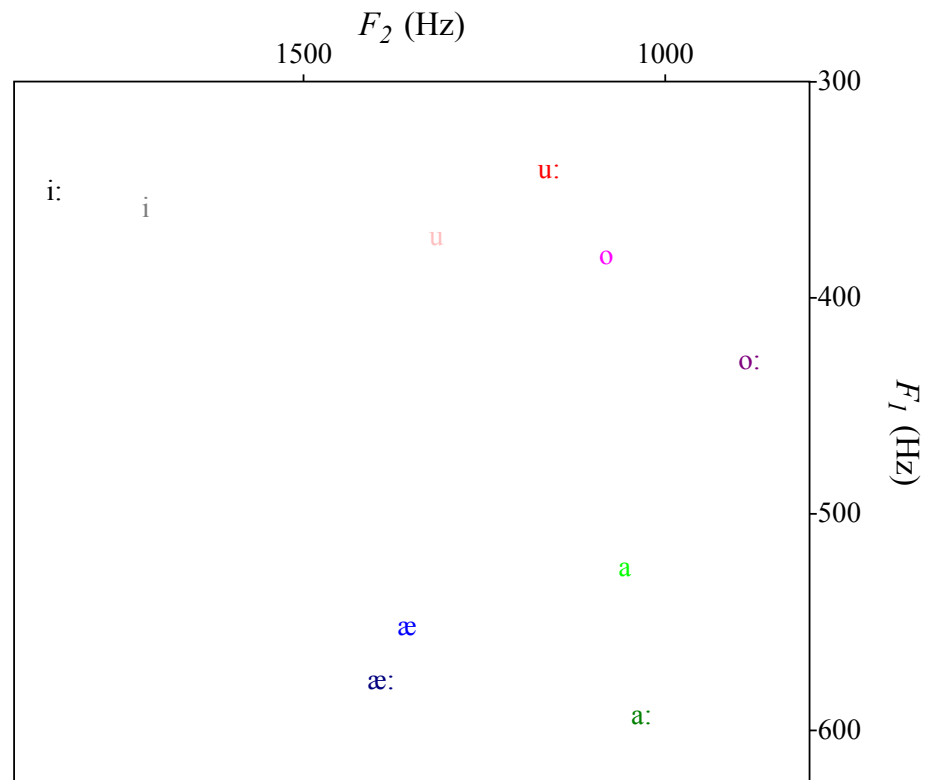


Figure 61 Averages for the monophthongs for MS2.

The difference between the long and short high front vowel is strong enough to claim that the short vowel is commonly produced as [ɪ] rather than [i]. While conducting the study I noticed that the short high front vowel is often realized as [ɪ]. In addition speakers told me, in reference to the spelling, *ii* is pronounced as [i:] and *i* is pronounced as [ɪ], regardless of stress. This, however, does not hold in every case. There are some instances where *ii* is pronounced as [ɪ] and *i* is pronounced as [i].

[o:] is backed in comparison to [o]. They do not differ much in height for FS1 but do differ for MS2. The other short and long vowel pairs tend to differ more in height than in frontness and backness.

Speakers show a distinct difference between the long and short monophthongs in both duration and to a lesser extent in vowel quality. The durational differences are not nearly as strong for the diphthongs and for one of the speakers (MS2) there appears to be essentially no difference between them. This may suggest that the long and short diphthongs are not as important to distinguish as the long and short monophthongs.

4.3.4. Phonation types and coarticulation

There are no phonemic differences based on phonation type in Nez Perce, however there is phonetic devoicing and creak often caused by coarticulatory effects.⁴⁴ Vowels are often partially devoiced word-finally and can be partially devoiced following ejectives. Devoicing following ejectives was predominantly seen in FS2, though creak following ejectives is one of the many differences between ejectives and plain stops. (For more information on the effects of ejectives on the following vowel see Section 2.3.1.) Figure 62 shows devoicing word finally for *'ipt'eese*, while Figure 63, *k'ik'et*, 'blood' also shows devoicing after an ejective word-medially, though when voicing begins it is creaky.

⁴⁴ As is common, there is phonetic nasalization on vowels preceding nasal stops.

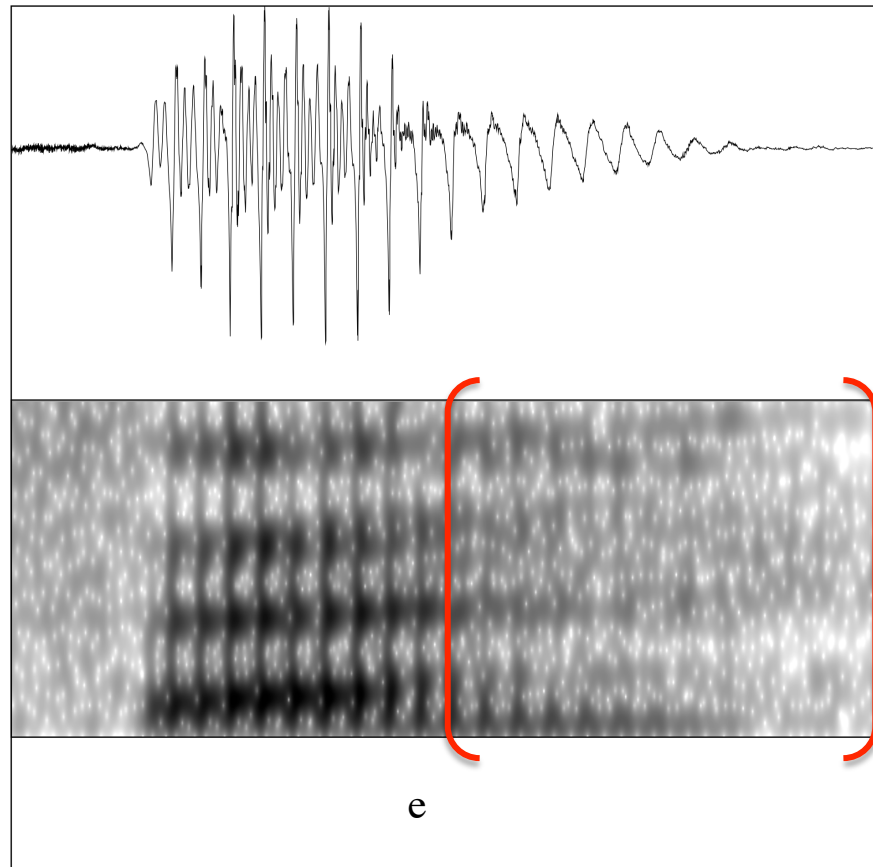


Figure 62 Word final devoicing for *i'pt'ese*, 'I hit' as spoken by FS1.

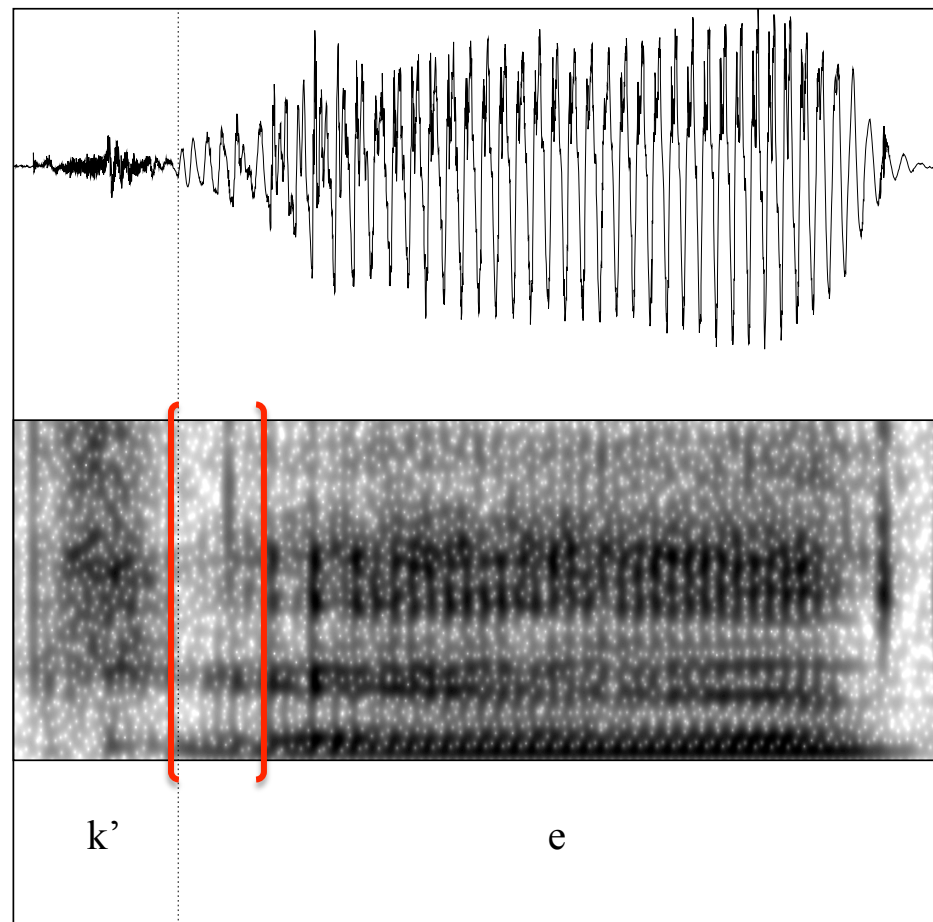


Figure 63 Post ejective devoicing and creak in the word *k'ik'et*, 'blood', as spoken by FS2.

Creak is common following ejectives and glottalized sonorants, word-finally as well as near glottal stops. As seen in Figure 63 the vowel following the ejective is devoiced until creaky phonation begins followed by modal phonation about a quarter of the way into the vowel.

Often times the glottal stop is only realized as creak on the following, preceding or both the following and preceding vowels (see Section 2.3.2 for further

discussion on the glottal stop). Figure 64 shows the effects of a word-final glottal stop on the preceding vowel. Modal phonation is seen until the last half of the vowel. Often the last portion of the vowel, as in Figure 64, is glottalized, but there are other instances where the majority of the vowel or the whole vowel is affected by the glottal stop.

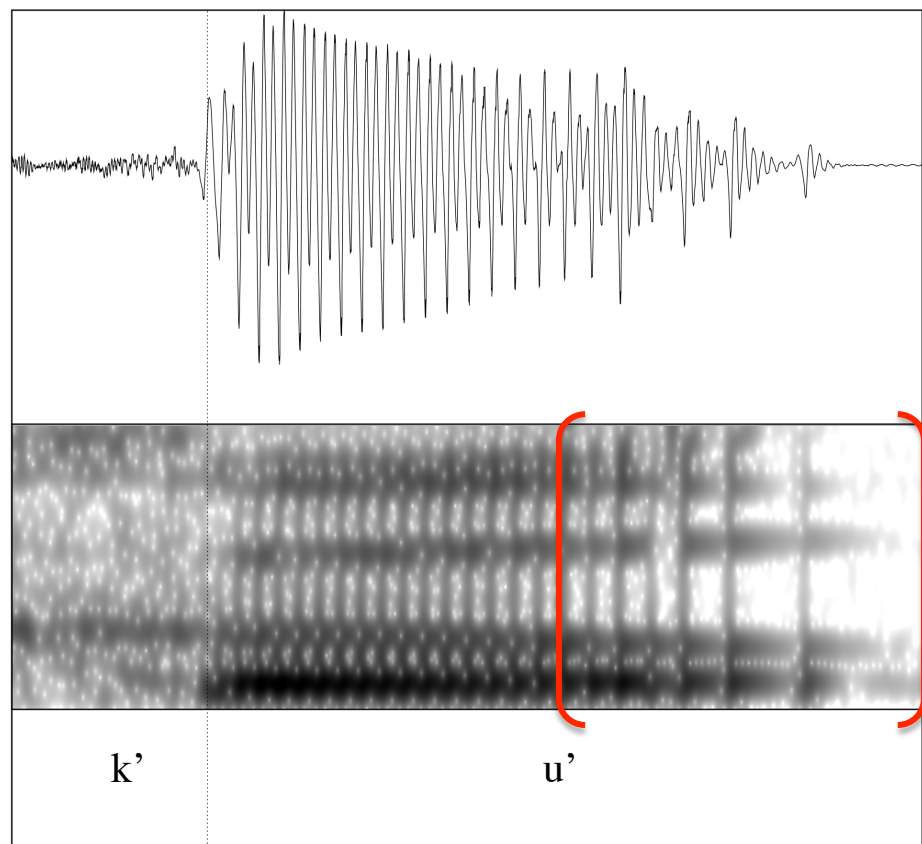


Figure 64 Effects of a glottal stop on the preceeding vowel in *t'ik'u'* 'yes, precisely, sure' as spoken by FS1.

Coarticulatory effects are common cross-linguistically, though how they are realized varies from language-to-language and speaker-to-speaker. This section

discussed the effects of ejectives and the glottal stops on surrounding vowels. A more in-depth analysis of these consonants and the following or preceding vowels can be found in Section 2.3.1 on ejectives, Section 2.3.2 on the glottal stop and Section 3.3.2 on glottalized sonorants.

4.3.5. Unstressed Vowels

This dissertation predominately utilizes stressed vowels because of the variation in the unstressed vowels. The variation in these vowels would require a completely separate study including primary stress, secondary stress and coarticulation. I can however provide some generalizations about the unstressed vowels, but further research is needed to substantiate these comments. Unstressed low vowels [a] and [æ] are often produced as schwa. [æ] can also be produced as [ɛ]. The high front vowel can be produced as either schwa or [ɪ]. The reduced [u] is produced similarly to [ʊ] and [o] similar to schwa.

4.4. Summary

In this chapter I studied the monophthongs and diphthongs of Nez Perce and provided vowel plots. I also discussed the similarity and differences of the Nez Perce vowel system to other vowel systems of the world. In addition this chapter exemplified the importance of an acoustic analysis by discussing the effects of surrounding segments on vowels, examining the differences between long and short vowels, and discussing vowel reduction. All of this information is lost without an

acoustic analysis. This analysis showed that the vowels in Nez Perce are indeed maximally contrastive and it provided support to the current phonological analyses of the Nez Perce vowels.

Chapter 5

Vowel Harmony

Nez Perce vowel harmony has been a much-discussed area of research due to the unique attributes of the vowel inventory and the rules of the vowel harmony system. Unlike other vowel harmony systems where there are clear unifying features for both the dominant set (the set that conditions vowel harmony) and recessive set (the set that does not condition vowel harmony), the Nez Perce vowels show no clear unifying features for either the dominant set or the recessive set. In addition to the lack of unifying features, the vowel harmony is both progressive and regressive, and any part of the word, stem or affix, could [historically] condition the vowel harmony.⁴⁵ In this chapter, I use acoustic data to investigate the structure of the vowel harmony system, providing an acoustic analysis of the vowel system. I

⁴⁵ Crook finds that for current speakers vowel harmony is predominantly conditioned by stems (1999: 247).

discuss the existing research on Nez Perce vowel harmony, why these studies have not provided a satisfactory analysis for the system, and suggest an alternate analysis.

5.1. Background

Since the first publications on the Nez Perce language, researchers have discussed the existence of vowel harmony in the language (Ainslie 1876 as cited in Aoki 1965, 1966 and Rude 1985; Phinney 1934; Morvillo 1888 and 1891 as cited in Aoki 1965, 1966 and Rude 1985).⁴⁶ Over the years researchers have continued to investigate the uncommon Nez Perce vowel harmony system (Aoki 1966; Zimmer 1968; Jacobsen 1968; Rigsby & Silverstein 1969; Zwicky 1970; Silverstein 1979; Hall & Hall 1980; Crook 1999; Bakovic 2000; MacKenzie & Drescher 2003). These studies have proposed different analyses of the system: advanced or retracted tongue root (Jacobsen 1968; Rigsby & Silverstein 1969; Zwicky 1971; Hall & Hall 1980; Bakovic 2000; MacKenzie & Drescher 2003) or two separate vowel systems (Crook 1999). In addition to the analysis of the current state of the Nez Perce vowel system, researchers have discussed the origin of this system. These analyses have included a vowel harmony system in the proto-language (Rigsby 1965; Rigsby & Silverstein 1969) and the development of two vowel systems from an umlaut

⁴⁶ I could not obtain all of these resources, Ainslie 1876, and Morvillo 1888, 1891. They are cited by other researchers including Aoki 1965, 1966 and Rude 1985.

system in the proto-language (Crook 1999: 251). They have also discussed the development of the five-vowel Nez Perce system from a three-vowel system (Rigsby 1965; Aoki 1966; Chomsky & Halle 1968: 377-378), a five-vowel system (Rigsby & Silverstein 1969), and a six-vowel system (Aoki 1963; Jacobsen 1968; Zwicky 1971) in the proto language.

All of the Nez Perce vowels are affected by vowel harmony, however, /i/ is in both the dominant and the recessive vowel sets. The dominant and recessive sets are shown in Figure 65. As can be seen they have no feature, which distinguishes the dominant vowels from the recessive vowels.

<u>Dominant</u>			<u>Recessive</u>		
	<u>Front</u>	<u>Central</u> <u>Back</u>		<u>Front</u>	<u>Central</u> <u>Back</u>
High	i		High	i	u
Mid		o	Mid		
Low	a		Low	æ	

Figure 65 Dominant and recessive vowel inventory (Crook 1999: 245).

We can investigate the Nez Perce dominant and recessive vowel inventories in terms of advanced or retracted tongue root (ATR or RTR), however, they do not appear to fit such an analysis. Many of the traits commonly seen in ATR languages with vowel harmony are not seen in Nez Perce. For example, the majority of vowel harmony systems which utilize ATR vowel harmony, such as Niger-Congo and Nilo-

Saharan languages, usually have seven vowels /i, e, ε, u, o, ɔ, a/ or nine vowels /i, ɪ, e, ε, u, ʊ, o, ɔ, a/ (Lindau 1979; Casali 2003). In an ATR vowel harmony analysis the dominant vowel set is usually +ATR while the recessive vowel set is –ATR (Hall & Hall 1980: 220-221; Casali 2003: 307). The vowel harmony analysis by Hall & Hall (1980) shows that if Nez Perce is indeed a language with ATR vowel harmony, then the dominant vowel set is –ATR while the recessive vowel set is the +ATR. This is the opposite of other ATR vowel harmony languages studied (Hall & Hall 1980: 220-221).⁴⁷

It is important to note that often in ATR languages there is either no ATR harmony in the low vowels or it was lost over the years. Furthermore, it is not uncommon for the low vowel in a vowel harmony language to be a neutral vowel, a vowel that does not participate in the vowel harmony process (Ohala 1994: 493), or for the low vowels to lose vowel harmony while the rest of the system retains the harmony distinction (Lindau 1979). In contrast, Nez Perce has a vowel harmony distinction in the low vowels, /a/ and /æ/, while it has lost (or never had) the distinction in the high front vowel, /i/.⁴⁸

In addition, the last vowel harmony pair, /o/ and /u/, are not of the same height. The results of the previous chapter (Chapter 4) do show however, that the

⁴⁷ Hall and Hall (1980) provide a detailed discussion of the vocal tract positions and vowel quality for ATR and RTR vowels and how it relates to Sahaptin, Nez Perce's sister language (217-224). Based on previous research on Sahaptin they suggest that Sahaptin vowels are RTR vowels.

⁴⁸ I will always list the dominant vowel first followed by the recessive vowel when discussing vowel harmony pairs.

/o/ is a high /o/, making the distinction between /o/ and /u/ smaller and more similar to other ATR vowel harmony pairs such as /o/ and /ɔ/ or /e/ and /ɛ/.

MacKenzie & Dresher (2003) and Bakovic (2000) facilitate their analysis of Nez Perce as an ATR system in part because they claim that /o/ is /ɔ/. In addition, Maddieson lists the vowel as /ɔ/ (1984: 371). Historically this vowel has been transcribed as /o/ (Aoki 1965, 1966, 1994; Rigsby & Silverstein 1969; Zwicky 1971; Hall & Hall 1980; Jacobsen 1968; Crook 1999). While I know of no previous study determining if this vowel is indeed /o/ the data in this dissertation show that the vowel is not /ɔ/ but is in fact a high /o/ (Section 4.3.1). It is unclear why MacKenzie & Dresher (2003) and Bakovic (2000) choose to use /ɔ/ other than it fits the ATR vowel harmony analysis.

According to the MacKenzie & Dresher (2003), /i/ was originally two vowels (a +ATR and -ATR vowel) that merged into one vowel. In their analysis they propose */ɛ/ as the second vowel. Although they do not explicitly states why they reconstruct */ɛ/, the use of */ɛ/ is most likely motivated by symmetry of the vowel system. Aoki (1966) also proposed that the /i/ developed from a merger of two vowels, however he suggests that it is the merger of */i/ and */ə/. In addition to these, there have been a number of other reconstructed vowel systems. Others have also proposed that the /i/ developed from the merger of */i/ and */i/ (Jacobsen 1968) or */i/ and */e/ (Rigsby & Silverstein 1969). These reconstructed forms can be seen in Figure 66 through Figure 69.

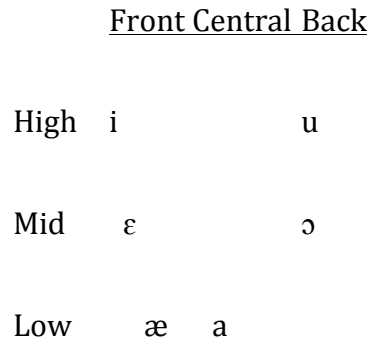


Figure 66 Reconstructed vowel inventory proposed by MacKenzie & Dresher (2003). */ɛ/ merged with the */i/.

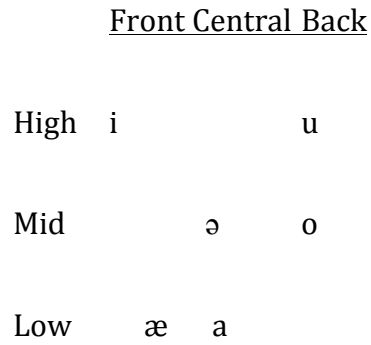


Figure 67 Reconstructed vowel inventory proposed by Aoki (1966), Jacobsen (1968), and Rude (1985). */ə/ merged with */i/.

	<u>Front Central Back</u>		
High	i	ɨ	u
Mid			o
Low	æ	a	

Figure 68 Second reconstructed vowel inventory proposed by Jacobsen (1968). */ɨ/ merged with */i/.

	<u>Front Central Back</u>		
High	i		u
Mid	e		o
Low	æ	a	

Figure 69 Reconstructed vowel inventory proposed by Rigsby & Silverstein (1969). */e/ merged with the */i/.

Rigsby & Silverstein (1969) suggest that Proto-Sahaptian had a five-vowel system */i, e, a, o, u/ with vowel harmony. Figure 70 provides a flow chart describing this process. In the chart, the blue boxes explain the current state described in the black boxes while the red boxes describe the process which causes the changes following the arrows. For example, the change between the first and second black box is that */i/ separates into a dominant and a recessive */i/, as described in the red box. The first blue box on the left explains that at the third black box Proto-Sahaptian has a dominant set, */i_{dom}, a, o/, and an recessive set, */i_{rec}, æ, u/, of vowels. Rigsby & Silverstein (1969) suggest that the */i/ in Proto-Sahaptian separated into a dominant and a recessive */i/. The Proto-Sahaptian */e/ unilaterally became */æ/. This made two vowel groups, the dominant vowels */i, a, o/ and the recessive vowels */i, æ, u/. Eventually the recessive Proto-Sahaptian */i/ was reanalyzed as */e/, for a system of dominant vowels */i, a, o/ and recessive vowels */e, æ, u/. Sahaptin and Nez Perce then deviate with Pre-Sahaptin palatalizing all */k/ and */k'/ to */tʃ/ and */tʃ'/ before */e, æ/ but not */i/. After this palatalization rule Pre-Sahaptin collapsed the six-vowel vowel harmony system to a three-vowel system with the palatalization being the only remnant of vowel harmony in the language. Pre-Nez Perce on the other hand retained the larger vowel inventory */i, e, æ, a, o, u/ with dominant vowels */i, a, o/ and recessive vowels */e, æ, u/ but collapsed the dominant */i/ and recessive */e/ to a dominant

and recessive */i/,⁴⁹ going back to a five-vowel system.⁵⁰ There is one dialect of Sahaptin, Palouse Sahaptin, which has both the palatalization seen in the other dialects of Sahaptin but also the five-vowel vowel harmony system seen in Nez Perce.

⁴⁹ The high front vowel appears as a neutral vowel in languages with palatalization harmony, such as Finno-Ugric and Altaic (Aoki 1968; Svantesson 1985)

⁵⁰ Rigsby & Silverstein (1969) support the separation of */i/ into a dominant and recessive */i/ in Proto-Sahaptian, followed by the dominant */i/ becoming */e/ and then shifting back to a dominant and recessive */i/ in Nez Perce and one */i/ in Sahaptin because each language treats words which historically had */e/ and */i/ differently. They can find no logical explanation for the realization of */i/ or */e/ in Nez Perce or Sahaptin based on historical reconstruction.

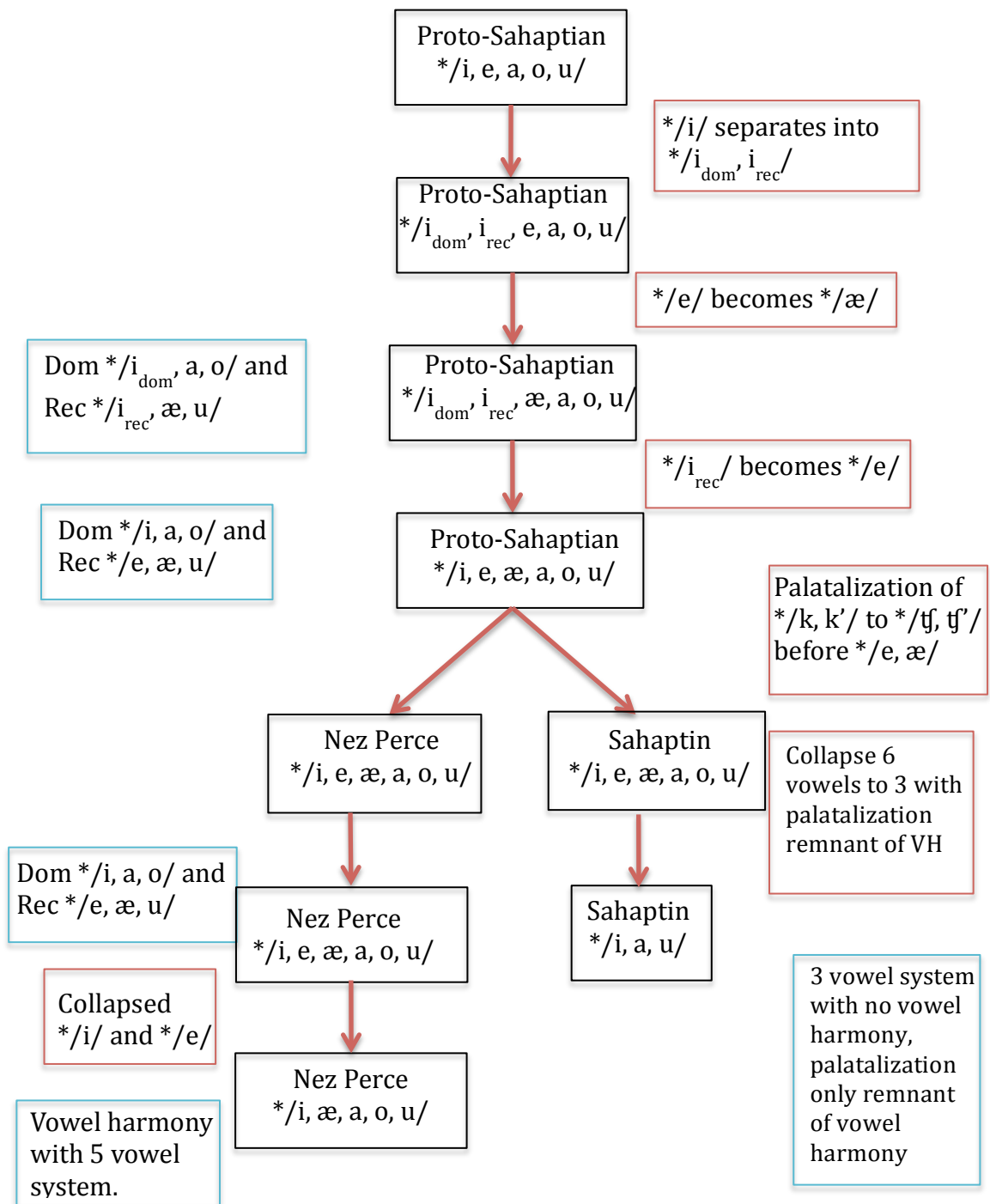


Figure 70 Flow chart pictorially describing the process outlined by Rigsby & Silverstein (1969). Blue boxes explain the current state described in the black boxes and the red boxes describe the process which causes the changes following the arrows.

Jacobsen (1968) examines the previous research on Nez Perce vowel harmony using the results from these studies as well as his own analysis to determine the most likely Proto-Sahaptian vowel system. He suggests a six-vowel system */i, ə, e, a, o, u/ without vowel harmony. He proposes the six-vowel system with */ə/ instead of */i/ as the dominant counterpart for */i/, as it allows for more natural dominant, */ə, e, u/, and recessive, */i, a, o/, vowel groupings and forms a dominant group which is backed and/or lowered from the recessive group. Jacobsen further suggests that there was no vowel harmony in Proto-Sahaptian because all evidence of vowel harmony is found Nez Perce. He notes that even though Rigsby & Silverstein (1969) find evidence in Pre-Sahaptin palatalization for vowel harmony in the language, Jacobsen points out that it is unnatural for the palatalization to have occurred only with the non-high front recessive vowels and not /i/.⁵¹

In contrast to the ATR analysis, Crook (1999: 243-254) proposes two separate vowel systems that developed from an umlaut system in Proto-Penutian described by Silverstein (1979). Morphemes in Nez Perce have vowels from one of the two sets: set one /i, a, o/ or set two /i, æ, u/, /i/ just happens to be in both sets. Crook explains the presence of /i/ in both vowel systems because it is the default

⁵¹ Palatalization is common cross linguistically before the high front vowel. Because it is so common it is possible that it did not act as a trigger for consonant change for */i/ like it did for */e, æ/.

epenthetic vowel for Nez Perce. He also says that the morphemes harmonize with each other at a morphological level.

Kim (1976) discussed the possibility that Nez Perce could be one of the rare “diagonal” vowel harmony systems. Kim presents an analysis of Nez Perce and Korean and finds that the diagonal system in Korean developed from a vowel shift in the language. He proposes that a similar shift or some change in the vowel inventory of Nez Perce led to its diagonal vowel harmony system.

Despite the unusual vowel inventory and vowel system of Nez Perce there are other languages which have a neutral high front vowel or a high front vowel that developed from a merger. Various dialects of Mongolian have a neutral high front vowel (Svantesson 1985), as does Hungarian (Booij 1984) and Finnish (Gordon 1999).

There have been no acoustic studies of Nez Perce vowels or vowel harmony. Previous studies on Nez Perce either do not mention an acoustic difference between the dominant and recessive /i/’s or say that there is no acoustic difference (Crook 1999: 245). Aoki (1968: 144) and Crook (1999: 245-6) have said that the /i/ is similar to a neutral vowel⁵² because of this apparent acoustic similarity. One /i/ conditions the vowel harmony and the other does not, meaning the Nez Perce /i/ cannot be a neutral vowel. Aoki writes that “neutral vowels seem to be products of

⁵² A neutral vowel is a vowel that does not participate in the vowel harmony process.

a low level phonological rule” (144), including the Nez Perce /i/. Despite the apparent lack of acoustic difference between the dominant and recessive /i/, it is not a neutral vowel because it participates in the vowel harmony system.

I investigated this vowel as though it were a neutral vowel, even though it is not a neutral vowel. This approach was motivated by Gordon (1999), who studied the neutral vowels of Finnish, which have progressive front/back vowel harmony, to determine if Finnish neutral vowels participate at a low level in the vowel harmony or if they are truly neutral and are realized the same in all contexts. Gordon finds that the second formants for these neutral vowels are significantly higher following front vowels than following back vowels. Using Gordon’s analysis as a model I examined the dominant and recessive /i/’s in Nez Perce to determine if there were any low level phonetic factors differentiating the two. The results of this analysis are compared to the other Nez Perce vowels to determine if the dominant and recessive /i/’s act similarly to /æ, a, o u/.

In addition to this analysis, I studied the vowel system for acoustic correlates of ATR vowels. I used the method and results from previous research on vowel harmony in ATR languages to inform my methodology. Lindau (1979), Hess (1992), Fulop, Kari & Ladefoged (1998), Anderson (2003), and Guion, Post & Payne (2004) have all studied ATR vowels for acoustic correlates to quantify the difference between +ATR and –ATR vowels. These researchers have used bandwidth, the

difference in the harmonics, formant frequencies (especially F1), and voice quality⁵³ to describe ATR vowels. ATR vowel systems are typified by the bright and breathy quality of the +ATR vowels while –ATR vowels are typified by their flat, hard or dull and sometimes creaky quality (Hall & Hall 1980: 206). Hall & Hall find that “[i]n the languages of this type with which we have worked intensively (Elgeyo, Bari, Toposa, Lotuko, Mabaan), the voice quality distinction in the non-high vowels had as a concomitant a noticeable distinction in tongue body position. In the high vowels voice quality was at times the only auditory cue” (1980: 206). The difference in the harmonics, the bandwidth, and the formant frequencies are examined because they are affected by changes in the pharyngeal cavity and are cues for voice quality.

These acoustic features and how well they describe an ATR languages’ vowels varies from language-to-language as well as from vowel-to-vowel. As previously mentioned Hall & Hall find in their research that often the only difference between the +ATR and –ATR high vowels is the voice quality. Anderson (2003) investigated the *ikpɔsɔ* language, a Kwa language (Niger-Congo), using the difference in harmonics and bandwidth because there is little to no difference in the acoustic space for /i/ and /ɪ/. Guion, Post & Payne (2004) investigated Maa, an Eastern-Nilotic language (Nilo-Saharan), finding F1 to be lower for +ATR vowels than for –ATR vowels, a larger difference in the harmonics for +ATR vowels than for –ATR vowels, and a durational difference for the back vowels. Their results differed

⁵³ Such as creaky, breathy, and modal.

from previous research on Maa that found a voice quality difference between the +ATR and –ATR vowels (Tucker & Mpaayei: 1955). These results also varied from speaker-to-speaker. Fulop, Kari & Ladefoged (1998) find that there is an F1 difference between the +ATR and –ATR vowels for all pairs except the [ə, a] in Degema, an Edoid language (Niger-Congo). F2 also shows a difference for some of the pairs and there is a difference in harmonics but only in two pairs of ATR vowels. Fulop, Kari & Ladefoged also conducted a perceptual study with native speakers of the language, who inconsistently identified the vowels based on formants alone except for mid vowels. In a study on Akan vowel harmony, a Kwa language (Niger-Congo), Hess (1992) found that both the F1 formant and the F1 bandwidth distinguish +ATR and –ATR vowels with the F1 bandwidth working the best. In a study of Akan, Lindau (1979) found that the larynx is lowered in +ATR vowel production. The larynx movement increases and decreases the volume of the pharyngeal cavity. Lindau used cineradiography to determine that tongue root advancement is a separate movement from tongue body movement. The separate movement of the tongue root and tongue body is one of the differences between ATR and tense/lax vowels (Ladefoged & Maddieson 1996: 303-6). The increase and decrease in vocal tract size changes vowel quality. This constriction of the pharyngeal cavity in –ATR vowels is what makes the vowels creaky, as mentioned previously (Hall & Hall: 1980).

I use these acoustic features (formants, bandwidths, the harmonic difference) to investigate the Nez Perce vowel harmony pairs for acoustic correlates of ATR.

The results of the study provide the phonetic evidence both supporting an ATR analysis but some of the data also suggest an alternate analysis.

The final aspect of Nez Perce vowel harmony that needs to be discussed is the current status of the system. According to Aoki (1966) and Crook (1999) speakers are losing the vowel harmony system. Crook writes that now vowel harmony is triggered primarily by dominant vowels in the stems, whereas historically any dominant vowel in any morpheme could trigger the harmony (Crook 1999: 247-249). The following two examples demonstrate how vowel harmony is primarily triggered by the vowel in the stem.⁵⁴

1. [tɛptɛp'ayn]
 /tɛptɛep-'ayn/
 butterfly.REC-for.the.DOM
 'for the butterfly'
2. [hototonóot]
 /hototo-noot/
 tabacco.DOM-without.REC
 'without the tobacco'

In the first example, the dominant vowel in the suffix does not trigger vowel harmony with the recessive vowel in the stem and in the second example the

⁵⁴ The following examples provide the [phonemic representation], <the orthography>, /the phonological information/, the morpheme-by-morpheme gloss and finally the free translation.

dominant vowel in the stem triggers vowel harmony with the recessive vowel in the suffix.

Crook provides further evidence demonstrating the loss of the vowel harmony system. He says that currently there is only one dominant inflectional suffix **-qa**, 'recent past', and a few dominant derivational suffixes which condition vowel harmony. He also says that there are no prefixes with dominant vowels, though there is some evidence that historically there were dominant derivational prefixes, but no dominant inflectional prefixes.

Aoki (1966) suggests that the high front vowel is possible evidence that Nez Perce is in the first steps of losing its vowel harmony. Assuming that the high front vowel, which is both dominant and recessive, did develop from a merger of two vowels and the Nez Perce vowel system is representative of the system in Proto-Sahaptian, then Nez Perce is losing the vowel harmony (Aoki 1966: 766).

It is clear that despite the above discussion of vowel harmony loss, speakers are still very aware of and use the vowel harmony system. When recording data for this dissertation, there was one case where a speaker did not use vowel harmony but she quickly corrected herself. This does not mean that Nez Perce is actually losing its vowel harmony, but suggests that over the years the vowel harmony system has undergone changes. It may mean that the vowel harmony system is no longer as productive as it once was, however, at this point speakers are still very aware of the process.

5.2. Data and Methodology

Data for this chapter were collected during Summer 2011 in Lapwai, Idaho. The word list used in this study was compiled using Aoki's *Nez Perce Dictionary* (1994), Crook's dissertation (1999), language learning materials (NPLP 2002a, 2002b, 2003, 2004, 2007, 2010a, 2010b, 2010c, 2010d, 2010e, ND; NPLP & Crook ND), and native speakers. Words chosen from the above texts, were examined by native speakers and archaic words were eliminated. In addition, ungrammatical constructions were corrected or eliminated. Words deemed suitable were compiled into a final word list. The words used in the study had the structure of stem-stem or stem-suffix. To facilitate comparisons I primarily used noun-suffix paradigms. The stem-stem and stem-affix combinations I used were of the following structures: dominant-dominant, dominant-recessive, recessive-dominant, and recessive-recessive.⁵⁵

I recorded the native speakers in quiet rooms using a Zoom H4n recorder and an AKG C555L head-mounted microphone with an AKG MPA VL adapter. Speakers were prompted with the English translation and responded in Nez Perce. They were then asked, in Nez Perce, to repeat the word in a Nez Perce carrier

⁵⁵ Recessive-dominant combinations do not tend to undergo vowel harmony, which means that there are some examples in the data of a recessive stem with a dominant suffix where the stem does not undergo vowel harmony. The vowels in these examples were labeled based on the speakers' production. For example, in *ʔepʔep'ayn*, the <e> was produced as [æ] rather than harmonizing to the [a]. This is also reflected in the orthography.

phrase or in isolation.⁵⁶ Speakers said the word two or three times depending on time constraints.⁵⁷

Tokens were discarded due to mispronunciations, background noise, devoiced vowels (for the target vowels), or if upon analysis one of the aspects of study is not calculable (for example, formants, bandwidth or outliers). The exact number of tokens varies speaker to speaker for the previously stated reasons. FS1 (Female Speaker 1) had 194 tokens, FS2 (Female Speaker 2) had 189 tokens and FS3 (Female Speaker 3) had 195 tokens. This includes words that were repeated three times. For the formant analysis, these repetitions were averaged together for each speaker. Some words included multiple tokens used in the analysis. For the bandwidth and harmonics analysis the tokens were averaged by token type rather than by the set of three repetitions.

All statistical analyses were independent sample t-tests conducted using the statistics software PSAW. The t-tests were conducted on the vowel harmony pairs, dominant and recessive /i/, /a/ and /æ/, as well as /o/ and /u/, to determine if there are any statistically significant differences between any of the formants, bandwidths, or harmonics. An example of an independent sample t-test I ran is

56 Though carrier phrases are intended to elicit more natural speech I was told after using a carrier phrase, “Héenek'e ____ híce” (translation: ‘Say ____ again.’), that carrier phrases were in fact not very natural for these speakers, as the words were not being used in a conversation or story.

57 Not all speakers had enough time to repeat the words three times, so to ensure I collected each word on the word list some speakers only repeated the words twice.

comparing the bandwidths the tokens for /o/ and /u/ to determine if there is a significant difference between their means.

5.3. Results

The data in this study present a mixture of results. If the vowels are analyzed based on the harmonic differences and the first bandwidth, the results suggest that the vowels are indeed based on ATR. However, if they are analyzed based on F1 and the second bandwidth, they do not appear to support an ATR analysis. The initial analysis of the data included both stressed and unstressed vowels (SUV). This analysis did not provide concrete results so I conducted the same study again using stressed vowels (SV) only.⁵⁸ This analysis did not provide concrete results either. The data and results from both sets of data, the stressed and unstressed vowels (SUV) as well as the stressed vowels only (SV), are included in the following section. I am including both sets of data because there are instances where significant results are obtained using the SUV group, but the same result is no longer significant when examining the SV group. Along with these results is a discussion about the differences between the two sets and the implications for the analysis of the Nez Perce vowel harmony system.

⁵⁸ The unstressed vowels tend to reduce in unexpected ways in Nez Perce. I have noticed this in my own research as have other researchers working on the language (Harold Crook p.c. and Amy Rose Deal p.c.).

5.3.1. Vowel Plots

Vowel plots of the dominant and recessive vowels reveal that generally the dominant and recessive vowel sets do not occupy the same vowel space. This is illustrated in the following six vowel plots: Figure 71 and Figure 72 (FS1), Figure 73 and Figure 74 (FS2), and Figure 75 and Figure 76 (FS3). As these figures show, the dominant vowels are retracted from the recessive vowels, appear to be more compact than the recessive vowels, and are slightly lower than the recessive vowels. While there is no significant data for the dominant and recessive [i]'s, the dominant [i]'s are more compact than the recessive [i]'s.

FS1 shows a clear difference in F2 between [a] and [æ] but no difference in F1 for both the SV group, Figure 71, or the SUV group Figure 72. There is also a clear difference in F2 for [o] and [u]. [o] is situated lower and more back in both sets of data. There is no difference between the dominant and recessive [i], other than the dominant [i] is more concentrated than the recessive [i].

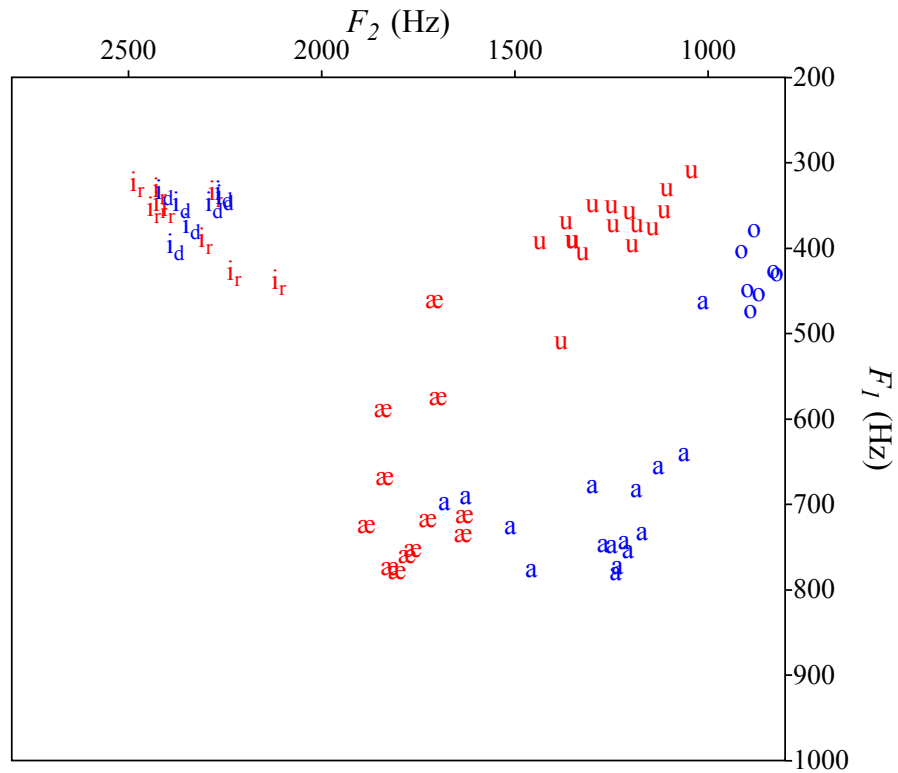


Figure 72 SUV (stressed and unstressed vowels) vowel harmony tokens for FS1.

FS2 displays a difference in F_2 between [o] and [u] as well as [a] and [æ]. There is also an F_2 difference with the recessive vowels [u] and [æ] concentrated higher than their dominant counterparts. As with FS1, there is little difference between the dominant and recessive [i], other than the dominant [i] is more concentrated than the recessive [i]. In addition there is little visual difference between the SV (Figure 73) and the SUV (Figure 74) groups.

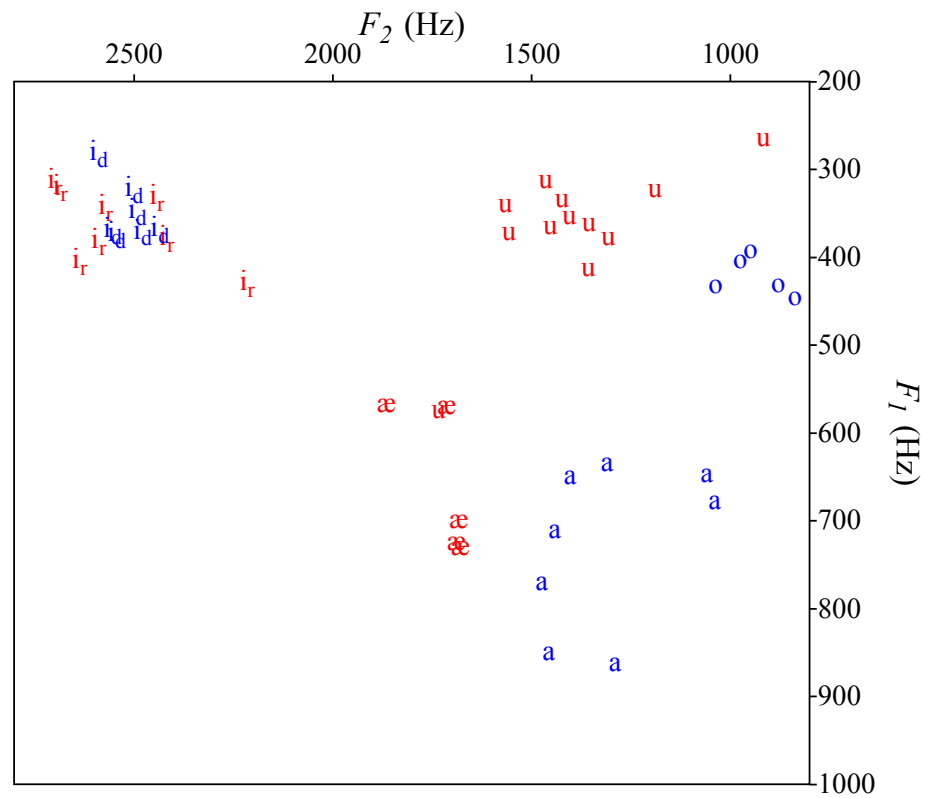


Figure 73 SV (stressed vowels) vowel harmony tokens for FS2.

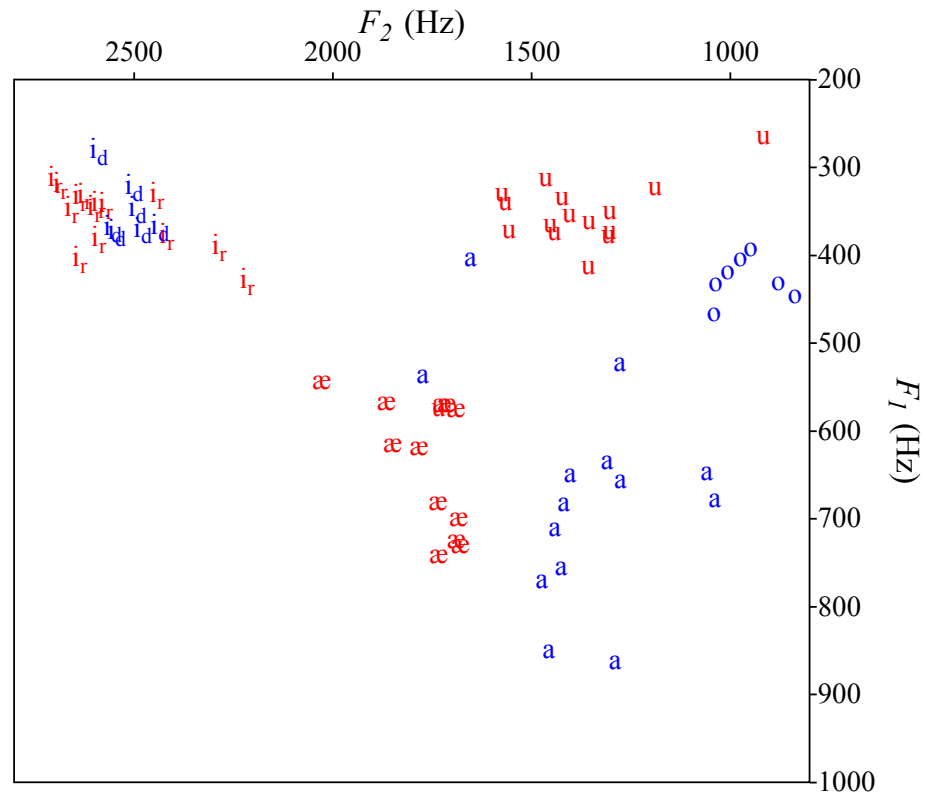


Figure 74 SUV (stressed and unstressed) vowel harmony tokens for FS2.

FS3 displays a difference between [o] and [u] in both F1 and F2. She also displays a difference between [a] and [æ] in both F1 and F2, though the F1 difference is clearer in the SV group, seen in Figure 75, than in the SUV group, seen in Figure 76. Again the only difference between the dominant and recessive [i]'s is that the dominant [i]'s are more concentrated than the recessive [i]'s.

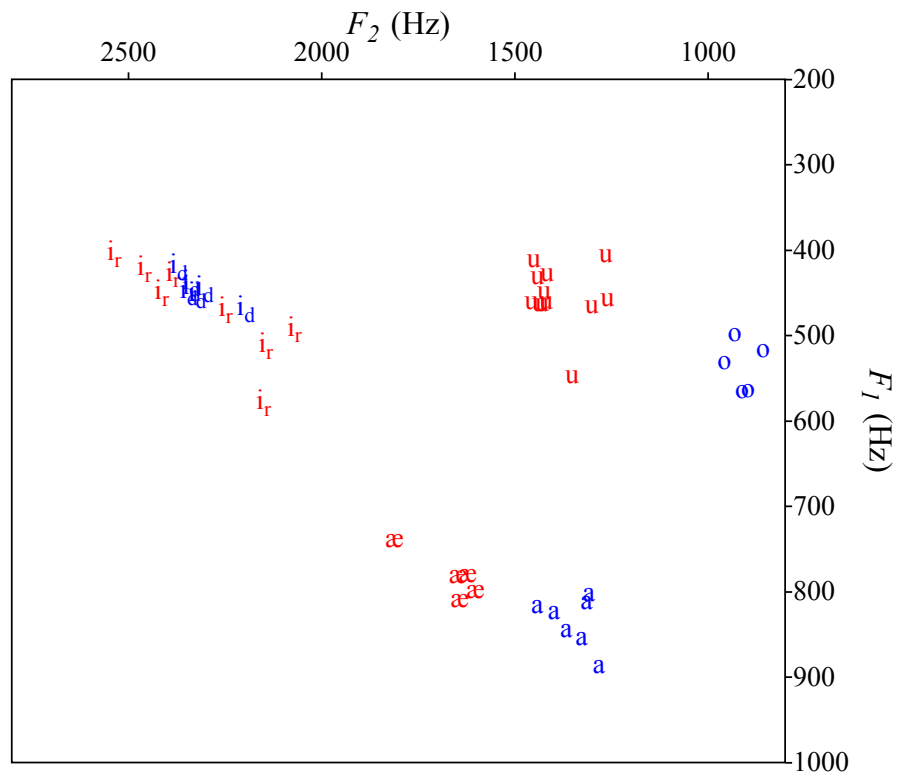


Figure 75 SV (stressed vowel) harmony tokens for FS3.

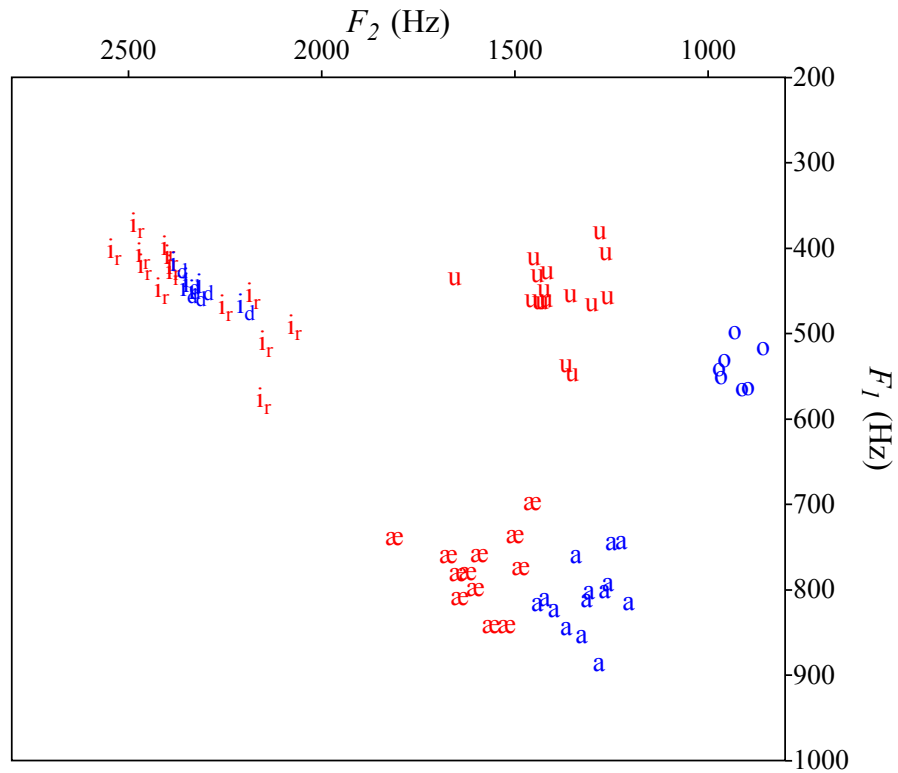


Figure 76 SUV (stressed and unstressed) vowel harmony tokens for FS3.

These plots show that there is a difference between all of the vowel harmony sets. The dominant and recessive [i]'s show this mainly in clustering, while the other groups also show the difference in F1 but mainly in F2. The plots also reveal that /o/ is not /ɔ/ but instead a high [o].

5.3.2. Formants

All three speakers show a difference in F2 for [a] and [æ] in both the SUV and SV data. This indicates that the main distinguishing feature for [a] and [æ] is F2. FS1 and FS2 show a significant difference in the third formant for [a] and [æ],

however FS1 shows this difference in the SV data while FS2 shows this distinction in the SUV group. This difference indicates that [a] is back in relation to [æ]. FS3 is the only speaker to show a significant difference in the first formant, seen in the SV group, which indicates that [a] is lower than [æ]. These results can be seen in Table 5. Because both the SUV (stressed and unstressed vowels) and the SV (stressed vowels) groups were studied, the more significant cell is bolded. In cases where both are equally significant both cells are bolded. (See Appendix F for complete results.⁵⁹)

⁵⁹I am only including the p-values here, but am providing the complete independent sample t-test results in the appendices.

Table 5 Average F1, F2 and F3 for all female speakers for [a] and [æ] with significance values determined by independent sample t-tests.

	FS1 stressed and unstressed	FS1 stressed only	FS2 stressed and unstressed	FS2 stressed only	FS3 stressed and unstressed	FS3 stressed only
Formant 1 [a] (-ATR)	704 Hz	739 Hz	667 Hz	724 Hz	806 Hz	833 Hz**
Formant 1 [æ] (+ATR)	687 Hz	757 Hz	635 Hz	657 Hz	776 Hz	780 Hz**
Difference/ Significance	17Hz <i>p</i> =0.595	18Hz <i>p</i> =0.324	32Hz <i>p</i> =0.427	67Hz <i>p</i> =0.213	30Hz <i>p</i> =0.068	53Hz** <i>p</i>=0.01
Formant 2 [a] (-ATR)	1283 Hz***	1205 Hz***	1377 Hz***	1307 Hz***	1313 Hz***	1347 Hz***
Formant 2 [æ] (+ATR)	1760 Hz***	1810 Hz***	1765 Hz***	1724 Hz***	1591 Hz***	1664 Hz***
Difference/ Significance	477Hz*** <i>p</i><0.001	605Hz*** <i>p</i><0.001	388Hz*** <i>p</i><0.001	417Hz*** <i>p</i><0.001	206Hz*** <i>p</i><0.001	317Hz*** <i>p</i><0.001
Formant 3 [a] (-ATR)	2888 Hz	2931 Hz*	2932 Hz*	2940 Hz*	2543 Hz	2538 Hz
Formant 3 [æ] (+ATR)	2837 Hz	2822 Hz*	2793 Hz*	2728 Hz*	2483 Hz	2463 Hz
Difference/ Significance	51 Hz <i>p</i> =0.188	109 Hz* <i>p</i>=.019	139 Hz* <i>p</i>=0.023	212 Hz* <i>p</i> =.035	60 Hz <i>p</i> =0.110	75 Hz <i>p</i> =0.208

All speakers show a significant difference between [o] and [u] for both F1 and F2, see Table 6. This difference is seen in both the SUV and the SV data. The SUV data show equal significance as the SV data for the second formant as well as the first formant for FS3. FS1 and FS2 show greater significance in the SUV group than in the SV group. These significant differences indicate that [o] is lower and more back than [u].

Table 6 Average F1 and F2 for all female speakers for [o] and [u] with significance values determined by independent sample t-tests.

	FS1 stressed and unstressed	FS1 stressed only	FS2 stressed and unstressed	FS2 stressed only	FS3 stressed and unstressed	FS3 stressed only
Formant 1 [o] (-ATR)	429 Hz**	431 Hz*	426 Hz**	420 Hz*	536 Hz***	533 Hz***
Formant 1 [u] (+ATR)	376 Hz**	377 Hz*	362 Hz**	365 Hz*	452 Hz***	452 Hz***
Difference/ Significance	53 Hz** <i>p=0.009</i>	54 Hz* <i>p=0.034</i>	64 Hz** <i>p=0.003</i>	55 Hz* <i>p=0.037</i>	84 Hz*** <i>p<0.001</i>	81 Hz*** <i>p<0.001</i>
Formant 2 [o] (-ATR)	871 Hz***	857 Hz***	959 Hz***	934 Hz***	926 Hz***	910 Hz***
Formant 2 [u] (+ATR)	1249 Hz***	1246 Hz***	1396 Hz***	1393 Hz***	1393 Hz***	1386 Hz***
Difference/ Significance	378 Hz*** <i>p<0.001</i>	389 Hz*** <i>p<0.001</i>	437 Hz*** <i>p<0.001</i>	459 Hz*** <i>p<0.001</i>	467 Hz*** <i>p<0.001</i>	476 Hz*** <i>p<0.001</i>

There are no significant differences in the formant data for the dominant and recessive [i]'s in either the SUV or the SV groups. This is shown in Table 7 below. This table shows that there is little difference between the dominant and recessive vowels or between the SUV or the SV groups. Though the difference is not

significant in all cases the F1 is equal to or higher for the recessive [i]'s. The F2 for FS1 and FS2 is also higher for the recessive [i]'s.

Table 7 Average F1, F2, and F3 for the dominant and recessive high front vowels for all female speakers with significance values determined by independent sample t-tests.

	FS1 stressed and unstressed	FS1 stressed only	FS2 stressed and unstressed	FS2 stressed only	FS3 stressed and unstressed	FS3 stressed only
Formant 1 [i] Dom (-ATR)	352 Hz	352 Hz	346 Hz	345 Hz	443 Hz	443 Hz
Formant 1 [i] Rec (+ATR)	382 Hz	358 Hz	355 Hz	361 Hz	443 Hz	467 Hz
Difference/ Significance	30 Hz $p=0.057$	6 Hz $p=0.714$	9 Hz $p=0.574$	16 Hz $p=0.465$	0 Hz $p=0.989$	24 Hz $p=0.273$
Formant 2 [i] Dom (-ATR)	2323 Hz	2323 Hz	2512 Hz	2512 Hz	2314 Hz	2314 Hz
Formant 2 [i] Rec (+ATR)	2346 Hz	2352 Hz	2545 Hz	2531 Hz	2334 Hz	2300 Hz
Difference/ Significance	23 Hz $p=0.537$	29 Hz $p=0.554$	33 Hz $p=0.463$	19 Hz $p=0.768$	20 Hz $p=0.662$	14 Hz $p=0.824$
Formant 3 [i] Dom (-ATR)	2722 Hz	2722 Hz	3081 Hz	3081 Hz	2926 Hz	2925 Hz
Formant 3 [i] Rec (+ATR)	2690 Hz	2966 Hz	3029 Hz	3087 Hz	2834 Hz	2882 Hz
Difference/ Significance	32 Hz $p=0.271$	244 Hz $p=0.471$	52 Hz $p=0.333$	6 Hz $p=0.931$	92 Hz $p=0.125$	43 Hz $p=0.526$

F1 is significant primarily in [o] and [u], though it shows significance in one speaker for [a] and [æ]. F2 is significant, however for both the SUV and SV groups for [o], [u] and [a], [æ]. This indicates that the main difference for the vowel pairs is in frontness and backness. Two speakers showed significance in F3 for [a] and [æ], however I doubt that F3 is important in determining the difference between these vowels.

5.3.3. Bandwidth and harmonics

Each speaker displays different results for the first and second bandwidths (B1, first bandwidth and B2, second bandwidth) and harmonics (A1-A2, the first amplitude minus the second amplitude). While some speakers only show a statistical difference in bandwidths, all speakers show some differences in the harmonics between the dominant and recessive vowels. Studies on ATR vowels have found that the difference in harmonics for the recessive vowels (+ATR) shows a larger difference than the dominant vowels (–ATR). In addition the recessive vowels' average first and second bandwidths is narrower than the dominant vowels' bandwidths for ATR languages.

The first female speaker (FS1), Table 8, shows a significant difference in the dominant and recessive [i]'s, and [o] and [u] in the SUV group but not the SV group. For [o] and [u], the +ATR vowel shows a larger difference in the harmonics than the –ATR vowel, following the pattern for ATR vowels. The dominant and recessive [i]'s, however, reverse this relationship and show a larger difference in the –ATR vowel

than the +ATR vowel. The SV group shows the expected relationship for the dominant and recessive [i]'s, with the +ATR vowel having a larger harmonic difference than the –ATR vowel, however this is not statistically significant.

All of the dominant vowels (–ATR) show a narrower second bandwidth than the recessive vowels (+ATR), which is opposite of other studies on ATR vowels, where the –ATR vowels have a wider bandwidth than the +ATR vowels. This is seen in SUV and the SV groups.

The dominant and recessive [i]'s are the only vowels to show a statistically significant result for the first bandwidth, though the expected relationship is reversed. This result can be seen in the SV group. None of the other vowels show a significant result for the first bandwidth, however it is narrower for +ATR vowels than for –ATR vowels, agreeing with studies of other languages with ATR vowels.

All of the following tables on bandwidths and amplitude difference show both SUV (stressed and unstressed vowels) and the SV (stressed vowels) groups. As with the tables on the formants the more significant cell is bolded. The tables with bandwidth and amplitude difference also have italicized cells, which indicate significant results that are in opposition to what would be expected. Amplitude is measured in pascals (Pa) and the bandwidth in hertz (Hz).

Table 8 Average values for intensity and bandwidth for FS1.

	Average A1-A2 stressed and unstressed	Average A1-A2 stressed only	Average B1 stressed and unstressed	Average B1 stressed only	Average B2 stressed and unstressed	Average B2 stressed only
[i] dominant (-ATR)	28 Pa**	20 Pa	29 Hz	26 Hz*	124 Hz	104 Hz
[i] recessive (+ATR)	21 Pa**	34 Pa	54 Hz	40 Hz*	148 Hz	136 Hz
Difference/Significance	7 Pa** <i>p</i> =0.002	14 Pa <i>p</i> =0.104	25 Hz <i>p</i> =0.075	14 Hz* <i>p</i> =0.031	24 Hz <i>p</i> =0.286	32 Hz <i>p</i> =0.298
[a] (-ATR)	10 Pa	10 Pa	135 Hz	117 Hz	149 Hz	144 Hz
[æ] (+ATR)	13 Pa	13 Pa	116 Hz	80 Hz	203 Hz	238 Hz
Difference/Significance	3 Pa <i>p</i> =0.387	3 Pa <i>p</i> =0.586	19 Hz <i>p</i> =0.544	37 Hz <i>p</i> =0.325	54 Hz <i>p</i> =0.087	94 Hz <i>p</i> =0.174
[o] (-ATR)	9 Pa***	9 Pa**	138 Hz	154 Hz	76 Hz	86 Hz
[u] (+ATR)	22 Pa***	22 Pa**	81 Hz	78 Hz	135 Hz	117 Hz
Difference/Significance	13 Pa*** <i>p</i> <0.001	13 Pa** <i>p</i> =0.004	57 Hz <i>p</i> =0.108	76 Hz <i>p</i> =0.337	59 Hz <i>p</i> =0.053	31 Hz <i>p</i> =0.233

FS2, Table 9, shows a significant difference in the harmonics for [o] and [u] in the SUV group but not the SV group. [a] and [æ] show the same pattern with the

harmonic difference, larger for the +ATR vowel than for the –ATR vowel, though it is not significant. FS2 also shows significance in the first bandwidth for only the dominant and recessive [i]'s for both the SUV and SV groups. [a] and [æ] also show a significant difference in the second bandwidth for the stressed vowels following the expected pattern for ATR vowels, with the bandwidth for the +ATR vowel narrower than the –ATR vowel. [o] and [u] also shows a significant difference in the second bandwidth, but again similar to FS1, the bandwidth for the +ATR vowel is wider than for the –ATR vowel, opposite of previous research on ATR languages.

Table 9 Average values for intensity and bandwidth for FS2.

	Average A1-A2 stressed and unstressed	Average A1-A2 stressed only	Average B1 stressed and unstressed	Average B1 stressed only	Average B2 stressed and unstressed	Average B2 stressed only
[i] dominant (-ATR)	28 Pa	28 Pa	81 Hz*	81 Hz*	113 Hz	114 Hz
[i] recessive (+ATR)	27 Pa	27 Pa	46 Hz*	46 Hz*	128 Hz	122 Hz
Difference/ Significance	1 Pa <i>p</i> =0.578	1 Pa <i>p</i> =0.646	35 Hz* <i>p</i>=0.013	35 Hz* <i>p</i> =0.019	15 Hz <i>p</i> =0.512	8 Hz <i>p</i> =0.701
[a] (-ATR)	13 Pa	13 Pa	130 Hz	119 Hz	164 Hz	165 Hz*
[æ] (+ATR)	15 Pa	15 Pa	127 Hz	103 Hz	142 Hz	112 Hz*
Difference/ Significance	2 Pa <i>p</i> =0.531	2 Pa <i>p</i> =0.593	3 Hz <i>p</i> =0.891	16 Hz <i>p</i> =0.691	22 Hz <i>p</i> =0.304	53 Hz* <i>p</i>=0.046
[o] (-ATR)	13 Pa***	13 Pa	96 Hz	97 Hz	87 Hz**	77 Hz*
[u] (+ATR)	28 Pa***	28 Pa	72 Hz	78 Hz	180 Hz**	177 Hz*
Difference/ Significance	15 Pa*** <i>p</i><0.001	15 Pa <i>p</i> =0.052	24 Hz <i>p</i> =0.170	19 Hz <i>p</i> =0.636	93 Hz** <i>p</i> =0.004	100 Hz* <i>p</i> =0.024

FS3, Table 10, shows significance in the harmonics for all the vowels except for the dominant and recessive [i]'s. All of the recessive vowels (+ATR) have a larger difference in the harmonics than the dominant vowels (-ATR) in the SUV

group except for the dominant and recessive [i]'s. [o] and [u] are more significant in the SV group. In addition, [o] and [u] also show a significant difference in the first bandwidth for the SV group. There are no other significant results for any other vowels for bandwidth or harmonic difference. FS3 shows a narrower first bandwidth for the recessive vowels (+ATR) in all instances for both SUV group as well as for the SV group, though it is not significant. The +ATR vowels, however, show a wider second bandwidth than the –ATR vowels, similar to FS1 and FS2.

Table 10 Average values for intensity and bandwidth for FS3.

	Average A1-A2 stressed and unstressed	Average A1-A2 stressed only	Average B1 stressed and unstressed	Average B1 stressed only	Average B2 stressed and unstressed	Average B2 stressed only
[i] dominant (-ATR)	16 Pa	16 Pa	90 Hz	90 Hz	127 Hz	127 Hz
[i] recessive (+ATR)	15 Pa	15 Pa	66 Hz	66 Hz	139 Hz	139 Hz
Difference/ Significance	1 Pa $p=0.183$	1 Pa $p=0.206$	34 Hz $p=0.405$	34 Hz $p=0.405$	12 Hz $p=0.549$	12 Hz $p=0.549$
[a] (-ATR)	6 Pa	6 Pa	93 Hz	101 Hz	140 Hz	167 Hz
[æ] (+ATR)	10 Pa	10 Pa	76 Hz	85 Hz	147 Hz	168 Hz
Difference/ Significance	4 Pa** $p=0.003$	4 Pa $p=0.080$	17 Hz $p=0.208$	16 Hz $p=0.335$	7 Hz $p=0.706$	1 Hz $p=0.904$
[o] (-ATR)	8 Pa**	5 Pa**	89 Hz	115 Hz*	103 Hz	97 Hz
[u] (+ATR)	19 Pa**	19 Pa**	52 Hz	50 Hz*	130 Hz	133 Hz
Difference/ Significance	9 Pa** $p=0.004$	14 Pa** $p=0.003$	37 Hz $p=0.108$	65 Hz* $p=0.018$	27 Hz $p=0.294$	36 Hz $p=0.366$

The harmonic difference is the most reliable distinguishing feature for the dominant and recessive vowels. It is smaller for –ATR vowels than for +ATR vowels except for the dominant and recessive [i]’s. The first bandwidth is also reliable with the +ATR vowels showing a narrower bandwidth than the –ATR vowels. These results are not always significant, but they are consistent across speakers. Most speakers have a larger second bandwidth for the +ATR vowel than for the –ATR vowels, which is opposite of what would be expected for ATR vowel harmony.

5.4. Discussion

The results presented above lend some support to an ATR analysis of Nez Perce, however, I would not say it proves that the vowel harmony is indeed ATR based or that the vowels are ATR vowels with an alternate vowel harmony analysis. There is no consistent pattern across speakers for vowels in the data presented above. This variation may be due in part to the low number of tokens and few speakers.

The second bandwidth is larger for +ATR vowels than it is for –ATR vowels in nearly all instances except for one vowel pair, [a] and [æ], for FS2. This relationship is opposite of what would be expected from ATR vowels. The reversal of this relationship suggests an alternative analysis to ATR, or the loss of an ATR vowel harmony system.

In addition to the larger +ATR second bandwidth than the –ATR second bandwidth, little of the first formant data is significant. Looking at the vowel plots it is fairly clear that there is a difference in F1 between [a] and [æ] as well as [o] and [u], however this difference is not significant for [a] and [æ],⁶⁰ most likely due to variation in the data.

The most reliable distinction between the dominant and the recessive vowels is the harmonic difference, which is higher for the +ATR vowels than for the –ATR vowels. These results follow the expected pattern, lending support for an ATR analysis for Nez Perce in all instances except for the dominant and recessive [i]’s.⁶¹

Another result supporting an ATR analysis is the first bandwidth, where measurements for +ATR vowels are smaller than those for the –ATR vowels following the ATR pattern. This difference is not always significant, however in every vowel pair, the +ATR vowel has a narrower bandwidth than the –ATR vowel.

The speakers showed significant results for the second and third formants of [a] and [æ] and for the second formants of [o] and [u]. Some ATR languages, Degema for example (Fulop, Kari & Ladefoged 1998), show a difference in F2 between ATR vowels, though this difference did not appear in every language as each language and speaker can utilize varying aspects to differentiate the vowels.

⁶⁰ FS3 shows a significant difference in [a] and [æ] in the SV group but not the SUV group.

⁶¹ Two speakers have this relationship reversed for the dominant and recessive [i]’s, however the values only differ by one hertz, making them nearly equal.

There were no significant differences between the dominant and recessive [i]'s for any of the formants. There were some significant differences in bandwidth, providing a little evidence for an ATR relationship between the dominant and recessive [i]'s.

Considering the evidence presented above, I cannot conclusively prove or disprove that Nez Perce utilizes ATR in vowel harmony. However, due to the lack of significance and variation in the data, it appears that vowel harmony based on ATR is not productive at this point (if it was historically used in the language).

I propose a possible alternate analysis for Nez Perce vowel harmony based on the principle of maximal contrast (Liljencrants & Lindblom 1972). Within each set of vowels, [i, a, o] and [i, æ, u], the vowels are maximally dispersed. The phonemes for the vowels, /i, æ, a, o u/, are also maximally dispersed even though there is no mid front vowel /e/. (For a discussion on vowel dispersion and the principle of maximal contrast in relation to the Nez Perce vowel system see Section 4.1.)

As seen in Figure 77, the dominant vowels are retracted in relation to the recessive vowels.

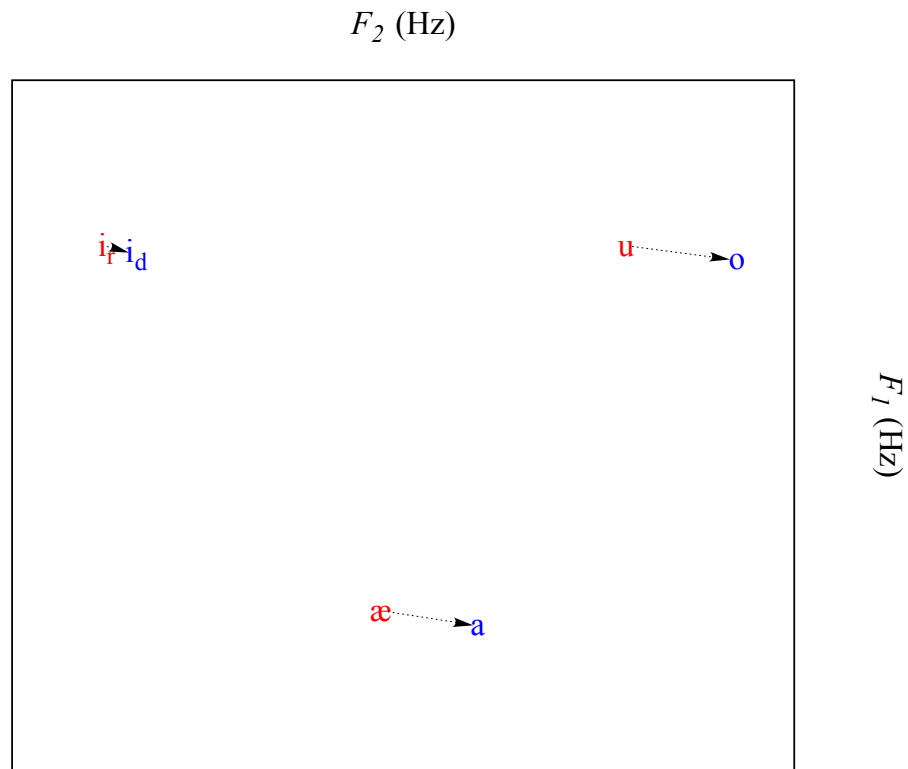


Figure 77 Vowel plot showing the retraction of the dominant vowels /i, a, o/ from the recessive vowels /i, æ, u/. Vowels in the this figure represent the general placement of the vowels and not any particular speaker.

/o/ and /u/ are at nearly the same height as are /a/ and /æ/, so the main difference between the dominant and recessive vowel pairs is that the dominant vowel is backed from the recessive vowel and the dominant vowels are more tightly clustered than the recessive vowels. There appears to be little to no difference in the dominant and recessive /i/'s other than the dominant [i]'s appears to be more tightly clustered than the recessive [i]'s, similar to the clustering pattern seen in the other pairs. As discussed in the background section, there may have historically been a difference between the dominant and recessive [i]'s, which was neutralized.

This neutralization could have led to the development of ATR to compensate for the inability to tell the difference between the two high front vowels.

The data discussed and analyzed in the chapter provide evidence that both supports and does not support an ATR analysis for Nez Perce. The vowel harmony system also displays evidence that the theory of maximal dispersion (Liljencrants & Lindblom 1972) plays an important part in the vowel system, suggesting a possible alternate analysis for the vowel harmony. Additionally, the dominant vowels are more tightly clustered than the recessive vowels suggesting that the hyperspace effect (Johnson, Flemming & Wright 1993) is also an important difference between the groups. The variation and lack of data supporting an ATR analysis suggests that Nez Perce does not currently rely on ATR for vowel harmony. ATR may have been productive in the past and further study of older recordings from the 1960s and working with other speakers of the language could shed light on the role ATR had in Nez Perce.⁶² In addition, study of larynx position would be helpful. Lindau (1979) finds that the larynx is significantly lower for +ATR vowels than for –ATR vowels. This lowering causes the pharyngeal cavity to be larger for the +ATR vowels. Though the current data does not appear to support an ATR analysis for Nez Perce, studying the larynx position could provide more concrete results either supporting or rejecting an ATR analysis.

⁶² The Nez Perce language program has extensive recordings from previous researchers and from their own work on the language that could be examined to gather more data.

Crook (1999: 247-249) and Aoki (1966: 766) state that Nez Perce is losing its vowel harmony system, leading to the question of why Nez Perce losing its vowel harmony system. As linguists we know that languages change and evolve over time for many reasons. One such reason is language contact. It is highly possible that the Nez Perce vowel system has been affected by contact with the English language, other Indigenous languages surrounding it, or other European languages spoken by immigrants to Nez Perce territory. European languages do not utilize an ATR vowel system, but a tense/lax distinction. It is possible that as English has come to be spoken more often and entered daily life, the ATR vowel system has been or is being replaced by a tense/lax distinction.

Other American Indigenous languages spoken in areas adjacent to Nez Perce may have affected the vowels and vowel harmony system.⁶³ Some of the languages surrounding Nez Perce do have vowel harmony: Coeur d'Alene (rounding, Doak 1992), Northern Paiute (height, Thornes 2003: 44-50), Shoshone⁶⁴ (rounding/height, Dayley 1989: 414-6), and Palouse Sahaptin (perhaps ATR, Rigsby & Silverstein, 1969). To my knowledge, however, no other language bordering Nez Perce uses an ATR vowel system. As mentioned in Section 5.1, Palouse Sahaptin had the same vowel inventory and vowel harmony system as Nez Perce, and it is thought that other Sahaptin dialects had vowel harmony at some point in history, which is

⁶³ The amount of contact between Nez Perce and the surrounding languages varies and an in-depth discussion of the contact is beyond the scope of this chapter.

⁶⁴ The information about Shoshone is about Tümpisa (Panamint) Shoshone.

now seen only in the palatalization of velars before /e/ and /æ/. It is still unknown what the vowel harmony system was in Palouse Sahaptin. Any of these languages could have affected the Nez Perce vowel system. We also do not know when Nez Perce started to lose the vowel harmony system and unfortunately we will probably not be able to determine this.⁶⁵

The data points toward an analysis based on maximal dispersion with the possibility that ATR was historically present. Further study of older recordings and working with more speakers would provide further evidence for this analysis. Also investigating other languages described as not maximally would be beneficial to this analysis (see Section 4.3.1 and Section 4.4). If these languages show a reliance on maximal dispersion on a shifted axis, it would lend support to an analysis based on maximal dispersion for the vowel harmony in Nez Perce. Until such a study is conducted, I will wait to determine how Nez Perce vowel harmony fits into Proto-Sahaptian and Penutian.

5.5. Summary

The above study presents some data supporting an ATR analysis (harmonic difference and the first bandwidth), however further research needs to be conducted (larynx position, studying older recordings). Though other languages

⁶⁵ We could determine this if Dr. Who stopped by or if I invented a time machine.

with ATR vowels show a great deal of variation, there is simply too much variation and inconclusive evidence in the current set of Nez Perce data to justify an ATR analysis. The main acoustic feature displaying this variation is the second bandwidth. The values in the second bandwidth are reversed for +ATR and –ATR vowels and the first formant does not often show significance between the vowel harmony pairs except for [o] and [u]. The first bandwidth does follow the ATR pattern with +ATR having a narrower bandwidth, lending support to an ATR analysis, but this is not significant for many speakers or vowels. The harmonic difference, formant two and formant three are the most consistent factors. Due to the reversal of the B2 results, the variation, and lack of F1 significance the current data does not lend support to an ATR analysis. It is possible that ATR was used historically but the speakers may have shifted to a vowel harmony system based on the principle of maximal dispersion. This analysis provides a possible alternate analysis for vowel harmony in the language. Additionally it could support the ATR historically while explaining the unusual dominant and recessive vowel sets.

Chapter 6

Conclusion

The purpose of this dissertation, as mentioned in the introduction, was threefold: (1) to document and analyze the sound system of the Nez Perce language, providing a database for linguistic comparison and description; (2) to aid in the preservation of the language; and (3) to provide a record of the sound system for use by the Nez Perce in the instruction of their language.

Chapter 2 provided additional information for the cross-linguistic study of ejectives and how they should be described. My previous work (Nelson 2010) proposed separating all of the features used to describe ejectives as stiff or slack, whereas previously these features had been generalized to provide a cover term for ejectives. Data from this chapter showed that Nez Perce ejectives display more features of slack ejectives than stiff ejectives.

The relatively rare and highly variable glottalized sonorants were discussed in Chapter 3. Data showed that the realization of Nez Perce glottalization varies. It is realized as laryngealization during part or all of the sonorant, a full glottal stop, both of these aspects, or as an increase in pitch. These findings supported Aoki's (1970) research except for the increase in pitch. Aoki found a decrease in pitch, which would be expected with creak, however I found an increase in pitch on the vowels preceding phonemically glottalized sonorants produced with modal phonation. Further research is needed to fully understand the interaction of these features in Nez Perce.

An acoustic description of the Nez Perce vowel space was provided in Chapter 4. All previous work had been conducted by ear, making this description the first instrumental work on the language's vowel system. This study led to reanalysis of the Nez Perce vowel system as maximally dispersed, while the canonical idea of maximal dispersion suggested that it was not.

Chapter 5 provided the first acoustic analysis of Nez Perce vowel harmony and suggested an alternate analysis based on the principle of maximal contrast and the hyperspace effect. This analysis does not rely on ATR, which fails to adequately describe the dominant and recessive vowel groups. I also investigated acoustic correlates of ATR to determine if Nez Perce vowels display ATR. This analysis provided evidence both for and against an ATR analysis, however the analysis based on hyperspace and maximal dispersion provides an analysis that encompasses all of the data.

The data in this dissertation provide multiple avenues for future research. I would like to investigate other languages with ejectives to determine if the acoustic correlates (intensity, f0, VOT, burst amplitude, and voice quality) are stiff or slack, and then compare these results to other languages. This more detailed analysis will hopefully lead to a better understanding of the different realizations of ejectives.

The glottalized sonorants also need further analysis to fully understand their production. The increase rather than decrease in pitch is intriguing and needs further analysis to determine if this pitch increase provides enough acoustic evidence for speakers to determine the difference between plain and glottalized sonorants.

The acoustic analysis of the vowels and vowel harmony generate the most intriguing research questions. The analysis suggests that speakers hear vowels as maximally contrastive but on a different axis. This suggests that the idea of maximal contrast is important to all speakers, just not based on the current description of maximal contrast.

The discussion in this dissertation on Nez Perce acoustics helps to further understand the capabilities of the human vocal tract and auditory system. Nez Perce in particular has multiple uncommon segments (glottalized sonorants, ejectives, and the unusual vowel harmony system). Acoustically analyzing Nez Perce phonetics provides valuable data about these segments as there are about 20

native speakers left. Better understanding these segments and the Nez Perce phonological inventory benefits not only the Nez Perce but also linguists.

Incorporating the knowledge gained by working with endangered and lesser-studied languages provides us with a deeper understanding of the possibilities of language and provides the speakers of these languages with tools for language education and preservation. Often times these languages contain uncommon segments and as they are lost so is the information that could be gained by understanding them.

My hope is that this description will be useful for the Nez Perce in their language instruction and preservation and for linguists in furthering their understanding of phonetic structures in the world's languages.

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Appendix A

The following five plots (Figure 78-Figure 82) show an alternative view of Figure 18. In these plots the plain stops (followed by the affricate) are listed together followed by the ejectives. These figures show the general increase in the VOT the more dorsal the POA becomes.

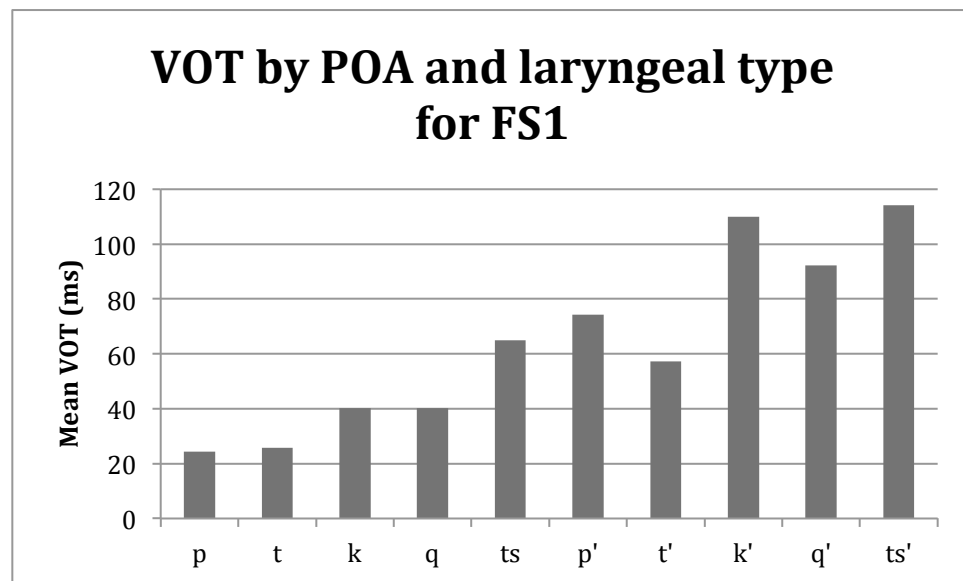


Figure 78 VOT by POA and laryngeal type for FS1

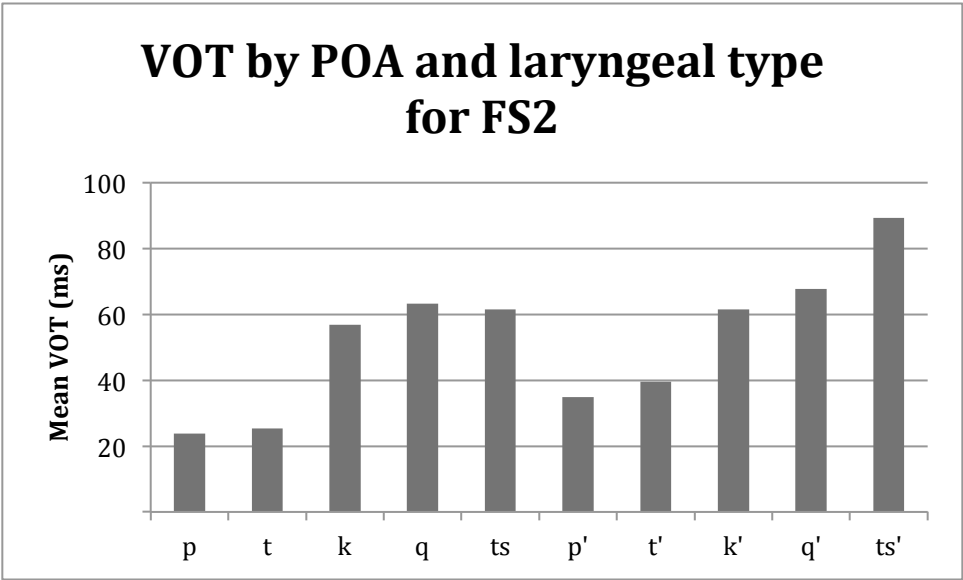


Figure 79 VOT by POA and laryngeal type for FS2

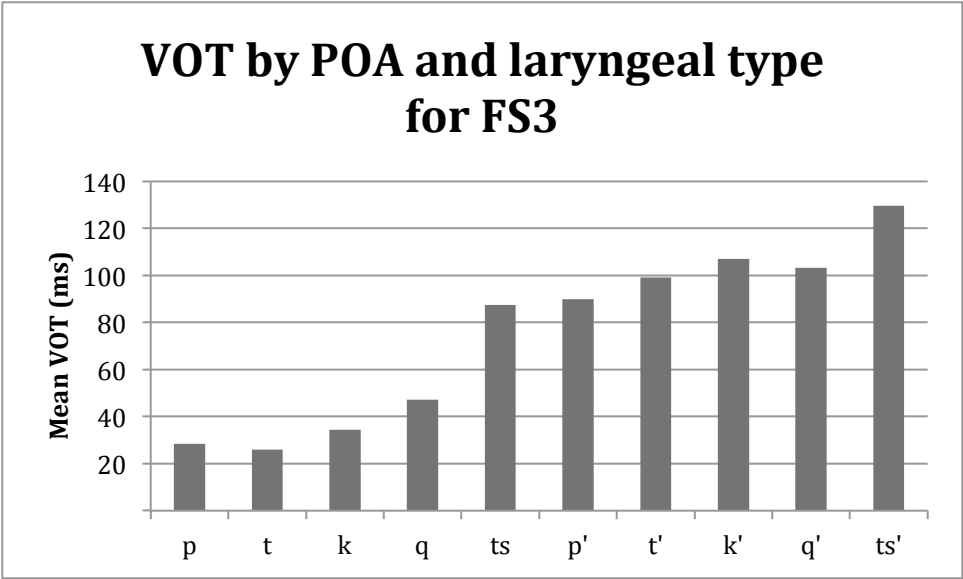


Figure 80 VOT by POA and laryngeal type for FS3

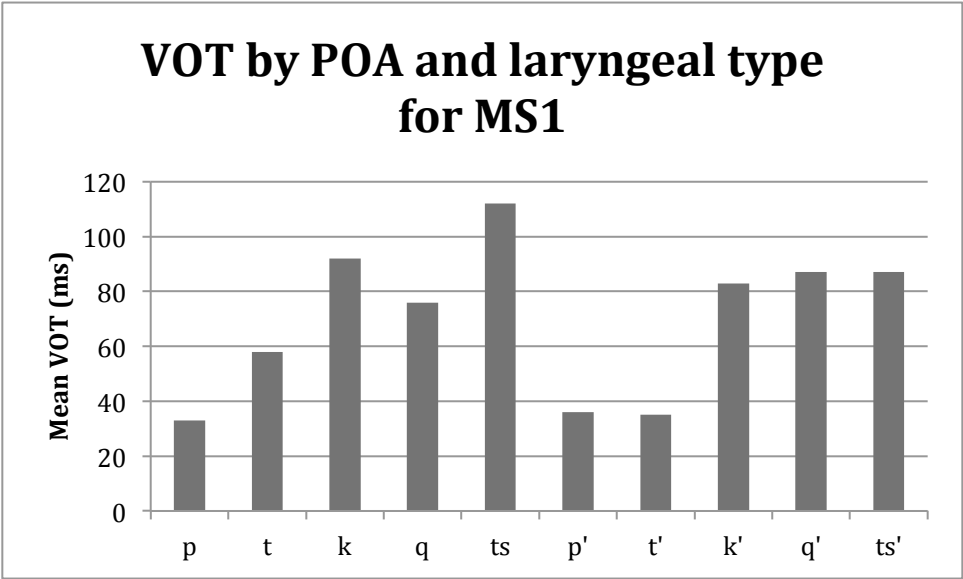


Figure 81 VOT by POA and laryngeal type for MS1

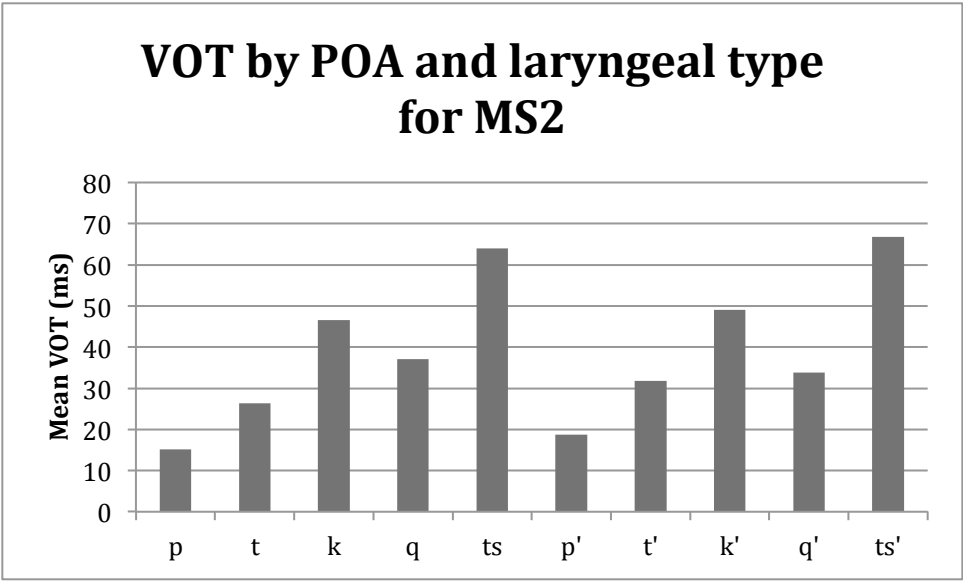


Figure 82 VOT by POA and laryngeal type for MS2

Appendix B

The following four figures (Figure 83-Figure 86) show the durational averages for the other four speakers. They show that the glottalized sonorants are generally longer than the plain sonorants.

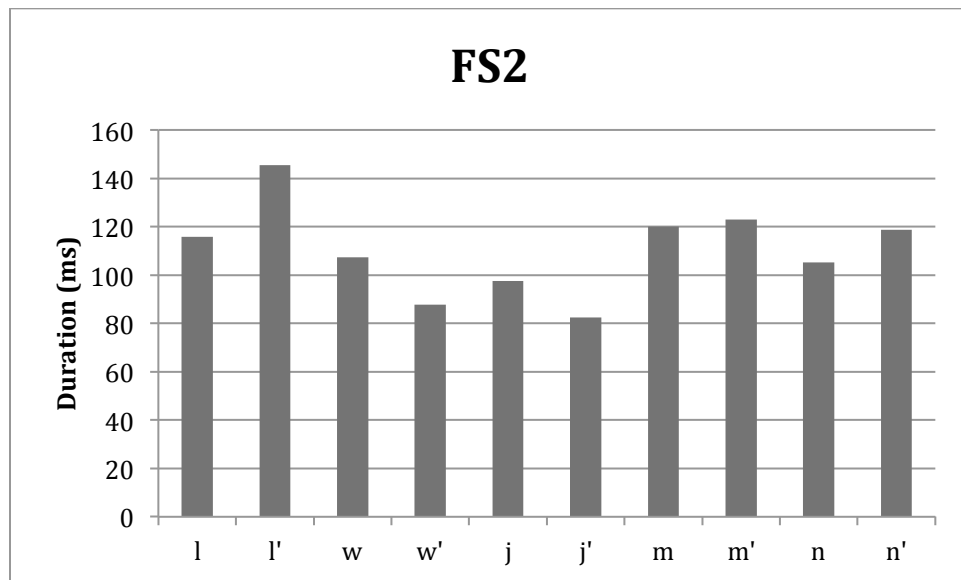


Figure 83 Durational values for glottalized sonorants for FS2

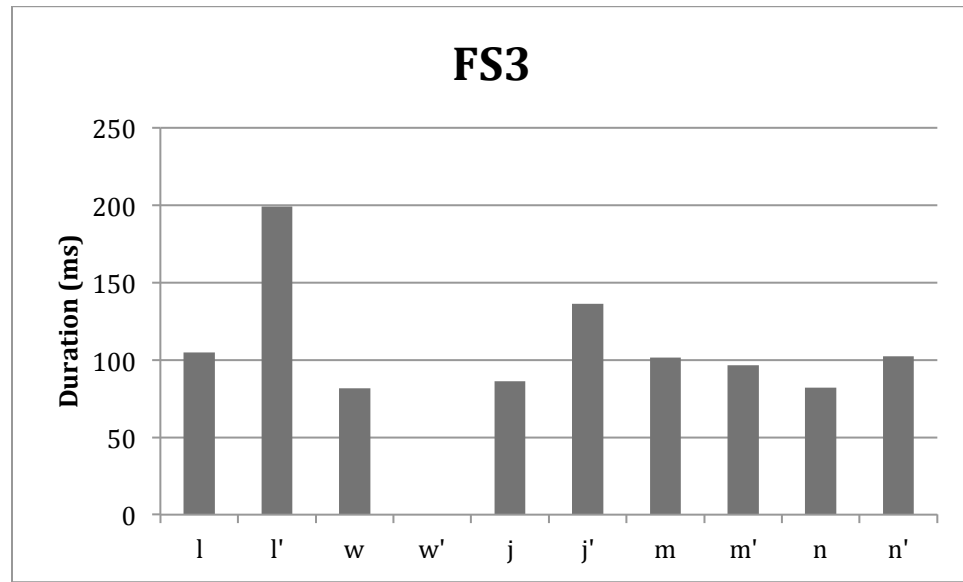


Figure 84 Durational values for glottalized sonorants for FS3

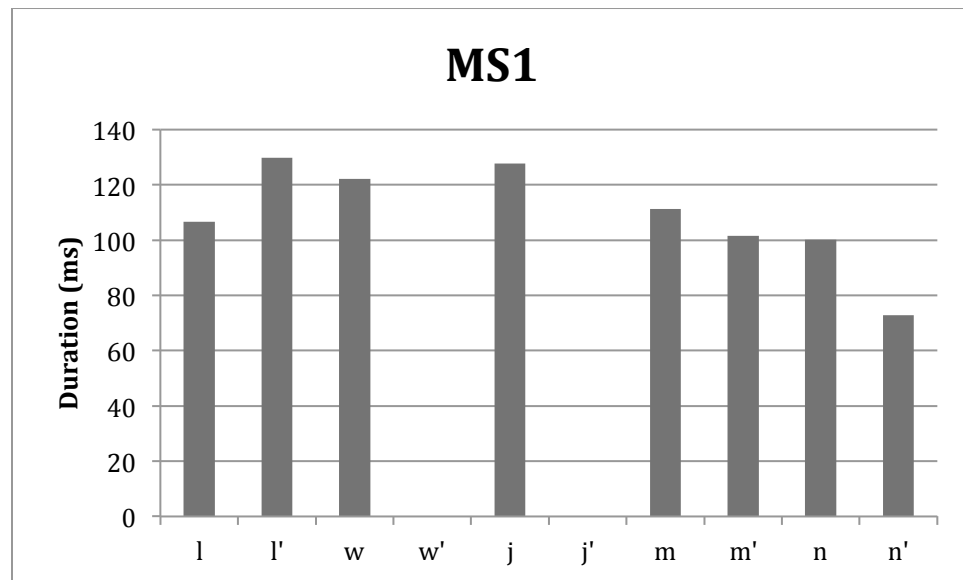


Figure 85 Durational values for glottalized sonorants for MS1

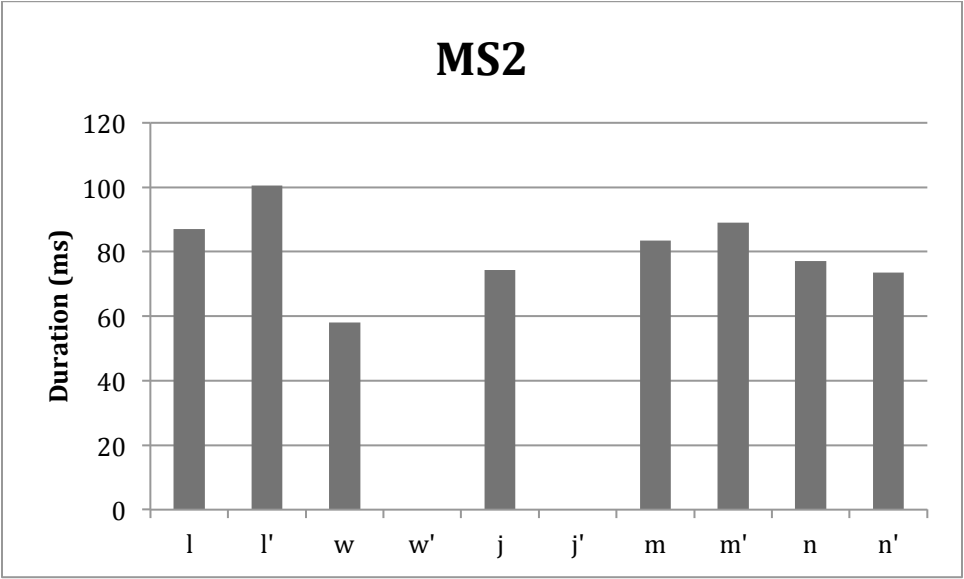


Figure 86 Durational values for glottalized sonorants for MS2

Appendix C

The following three plots (Figure 87, Figure 88, and Figure 89) show the long and short monophthongal vowels for FS1, FS3 and MS2. Vowel plots for FS2 and MS1 can be found in Section 4.3 on monophthongs.

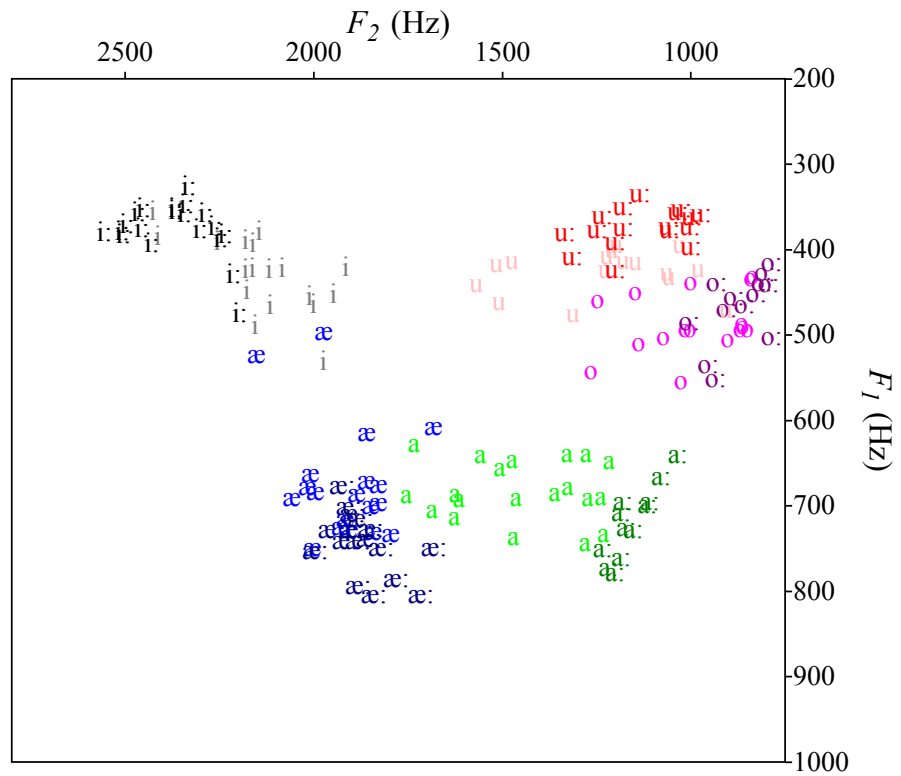


Figure 87 Long and short monophthong vowel plot for FS1

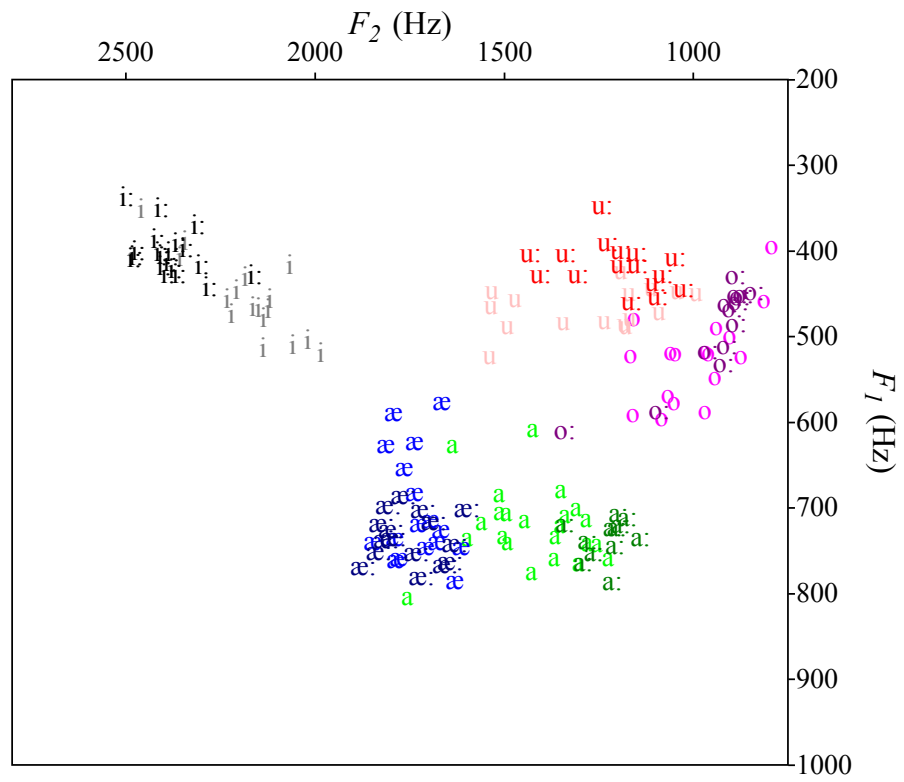


Figure 88 Long and short monophthong vowel plot for FS3

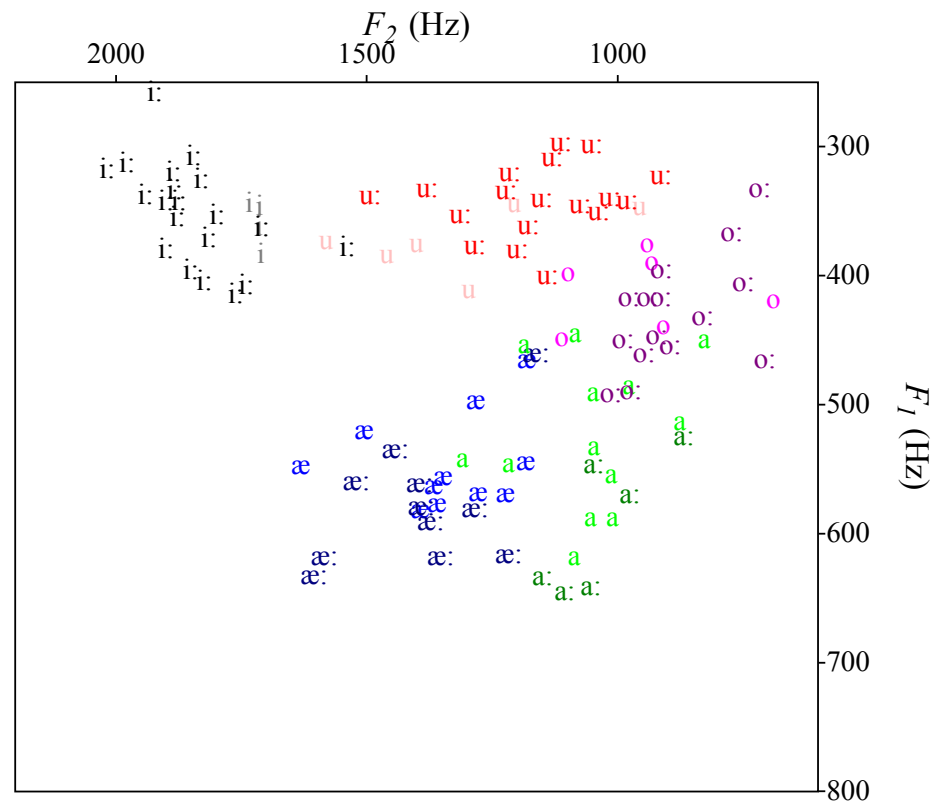


Figure 89 Long and short monophthong vowel plot for MS2

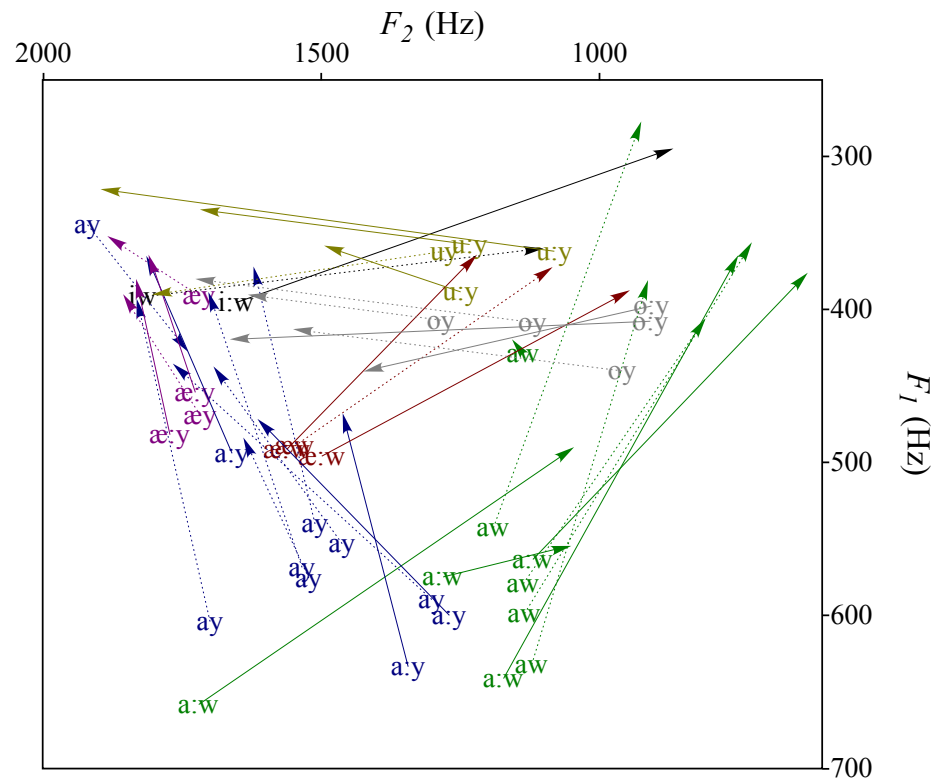


Figure 92 Long and short diphthong vowel plot for MS1

Appendix E

The following three plots (Figure 93, Figure 94, and Figure 95) show the average values for the monophthongal vowels of Nez Perce for FS2, FS3, and MS1. Averaged vowel plots for FS1 and MS2 can be found in Section 4.3.3 on vowel length.

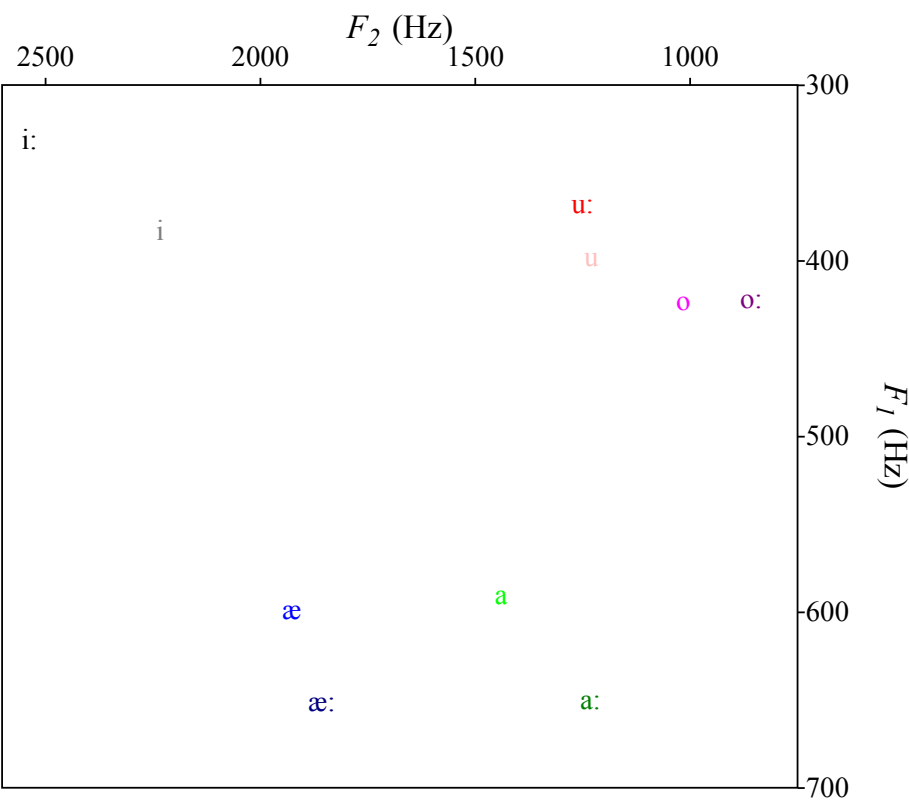


Figure 93 Average monophthongs for FS2

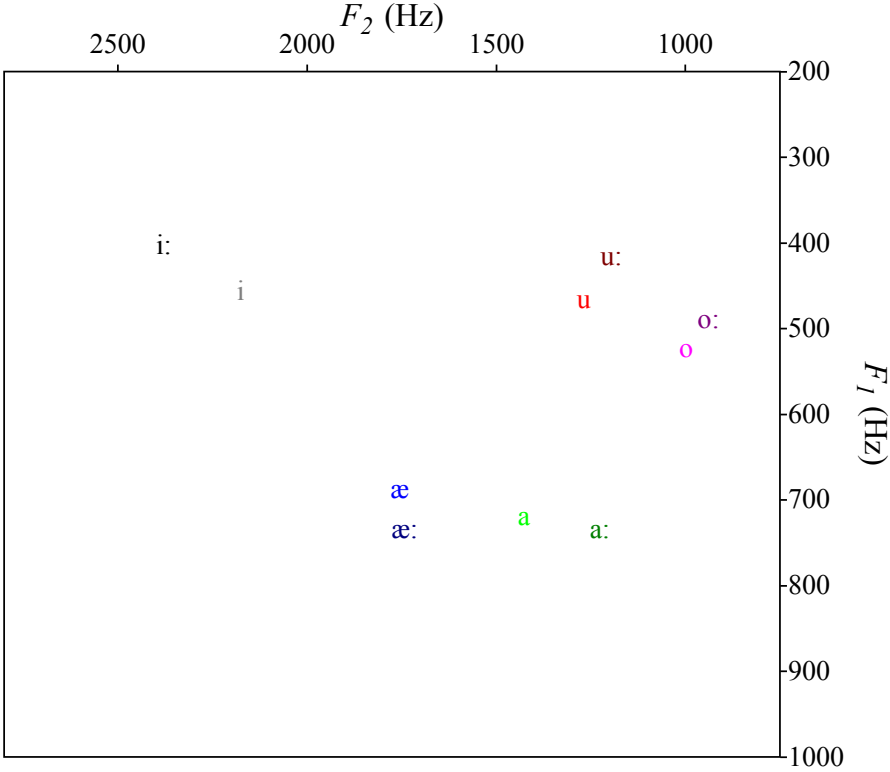


Figure 94 Average monophthongs for FS3

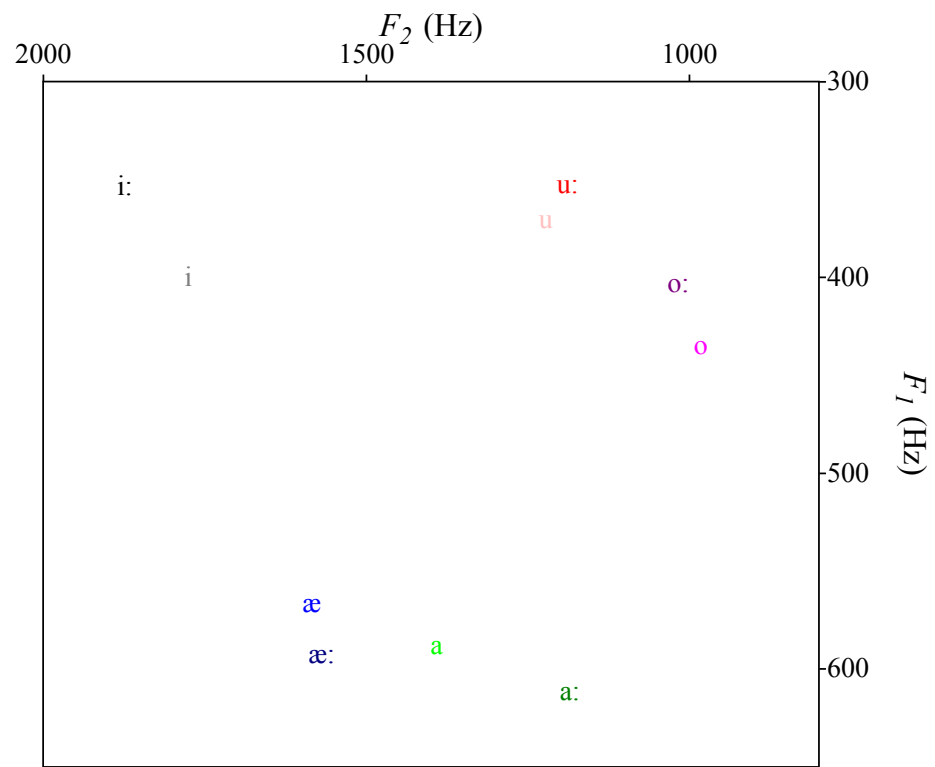


Figure 95 Average monophthongs for MS1

Appendix F

This appendix contains the details of the t-tests conducted on the vowel groups in Chapter 5. Each table has been copied from the chapter and the relevant t-test information has been added. All of the tables show both the SUV (stressed and unstressed vowels) and SV (stressed vowels) groups. The more significant cell is bolded. The tables with bandwidth and amplitude difference also have italicized cells, which indicate significant results that are in opposition to what would be expected. Amplitude is measured in pascals (Pa) and the bandwidth and frequency in hertz (Hz). Significance was determined by independent sample t-tests.

Table 11 Average F1, F2 and F3 for [a] and [æ] for all female speakers.

	FS1 stressed and unstressed	FS1 stressed only	FS2 stressed and unstressed	FS2 stressed only	FS3 stressed and unstressed	FS3 stressed only
Formant 1 [a] (-ATR)	704 Hz	739 Hz	667 Hz	724 Hz	806 Hz	833 Hz**
Formant 1 [æ] (+ATR)	687 Hz	757 Hz	635 Hz	657 Hz	776 Hz	780 Hz**
Difference/ Significance	17Hz $t(26)=0.38$, $p=0.595$	18Hz $t(10.64)=$ 19.28, $p=0.324$	32Hz $t(21.62)=$ 0.81, $p=0.427$	67Hz $t(9.35)=$ 1.36, $p=0.213$	30Hz $t(24)=1.91$, $p=0.068$	53Hz** $t(10)=3.1$ 5, $p=0.01$
Formant 2 [a] (-ATR)	1283 Hz***	1205 Hz***	1377 Hz***	1307 Hz***	1313 Hz***	1347 Hz***
Formant 2 [æ] (+ATR)	1760 Hz***	1810 Hz***	1765 Hz***	1724 Hz***	1591 Hz***	1664 Hz***
Difference/ Significance	477Hz*** $t(21.60)=$ 9.0, $p<0.001$	605Hz*** $t(11)=$ 17.80, $p<0.001$	388Hz*** $t(20.26)=$ 6.38, $p<0.001$	417Hz*** $t(10.43)=$ 5.89, $p<0.001$	206Hz*** $t(24)=8.26$, $p<0.001$	317Hz*** $t(6.56)=$ 7.35, $p<0.001$
Formant 3 [a] (-ATR)	2888 Hz	2931 Hz*	2932 Hz*	2940 Hz*	2543 Hz	2538 Hz
Formant 3 [æ] (+ATR)	2837 Hz	2822 Hz*	2793 Hz*	2728 Hz*	2483 Hz	2463 Hz
Difference/ Significance	51 Hz $t(26)=1.35$, $p=0.188$	109 Hz* $t(11)=2.76$, $p=.019$	139 Hz* $t(24)=2.43$, $p=0.023$	212 Hz* $t(5.09)=$ 2.85, $p=.035$	60 Hz $t(21.33)=$ 1.67, $p=0.110$	75 Hz $t(9.32)=$ 1.35, $p=0.208$

Table 12 Average F1 and F2 for [o] and [u] for all female speakers.

	FS1 stressed and unstressed	FS1 stressed only	FS2 stressed and unstressed	FS2 stressed only	FS3 stressed and unstressed	FS3 stressed only
Formant 1 [o] (-ATR)	429 Hz**	431 Hz*	426 Hz**	420 Hz*	536 Hz***	533 Hz***
Formant 1 [u] (+ATR)	376 Hz**	377 Hz*	362 Hz**	365 Hz*	452 Hz***	452 Hz***
Difference/ Significance	53 Hz** $t(21)=2.90$, $p=0.009$	54 Hz* $t(15)=2.33$, $p=0.034$	64 Hz** $t(20.89)=3.35$, $p=0.003$	55 Hz* $t(14.34)=2.29$, $p=0.037$	84 Hz*** $t(18.86)=6.02$, $p<0.001$	81 Hz*** $t(15)=4.43$, $p<0.001$
Formant 2 [o] (-ATR)	871 Hz***	857 Hz***	959 Hz***	934 Hz***	926 Hz***	910 Hz***
Formant 2 [u] (+ATR)	1249 Hz***	1246 Hz***	1396 Hz***	1393 Hz***	1393 Hz***	1386 Hz***
Difference/ Significance	378 Hz*** $t(19.72)=12.03$, $p<0.001$	389 Hz*** $t(14.54)=12.40$, $p<0.001$	437 Hz*** $t(21.00)=7.95$, $p<0.001$	459 Hz*** $t(15.00)=6.66$, $p<0.001$	467 Hz*** $t(21.00)=16.06$, $p<0.001$	476 Hz*** $t(14.03)=17.62$, $p<0.001$

Table 13 Average F1, F2, and F3 for the dominant and recessive high front vowels for all female speakers.

	FS1 stressed and unstressed	FS1 stressed only	FS2 stressed and unstressed	FS2 stressed only	FS3 stressed and unstressed	FS3 stressed only
Formant 1 [i] Dom (-ATR)	352 Hz	352 Hz	346 Hz	345 Hz	443 Hz	443 Hz
Formant 1 [i] Rec (+ATR)	382 Hz	358 Hz	355 Hz	361 Hz	443 Hz	467 Hz
Difference/ Significance	30 Hz $t(18.61)=$ 2.03, $p=0.057$	6 Hz $t(11.86)=$ 0.38, $p=0.714$	9 Hz $t(19)=0.57$, $p=0.574$	16 Hz $t(13)=$ 0.75, $p=0.465$	0 Hz $t(16.48)=$ 0.01, $p=0.989$	24 Hz $t(8.10)=$ 1.18, $p=0.273$
Formant 2 [i] Dom (-ATR)	2323 Hz	2323 Hz	2512 Hz	2512 Hz	2314 Hz	2314 Hz
Formant 2 [i] Rec (+ATR)	2346 Hz	2352 Hz	2545 Hz	2531 Hz	2334 Hz	2300 Hz
Difference/ Significance	23 Hz $t(17.83)=$ 0.63, $p=0.537$	29 Hz $t(10.90)=$ 0.61, $p=0.554$	33 Hz $t(17.78)=$ 0.75, $p=0.463$	19 Hz $t(8.55)=$ 0.31, $p=0.768$	20 Hz $t(18.31)=$ 0.45, $p=0.662$	14 Hz $t(8.70)=$ 0.23, $p=0.824$
Formant 3 [i] Dom (-ATR)	2722 Hz	2722 Hz	3081 Hz	3081 Hz	2926 Hz	2925 Hz
Formant 3 [i] Rec (+ATR)	2690 Hz	2966 Hz	3029 Hz	3087 Hz	2834 Hz	2882 Hz
Difference/ Significance	32 Hz $t(19)=1.14$, $p=0.271$	244 Hz $t(13)=0.74$, $p=0.471$	52 Hz $t(18.17)=$ 0.99, $p=0.333$	6 Hz $t(11.36)=$ 0.088, $p=0.931$	92 Hz $t(17.75)=$ 1.61, $p=0.125$	43 Hz $t(9.27)=$ 0.66, $p=0.526$

Table 14 Average values for intensity and bandwidth for FS1.

	Average A1-A2 stressed and unstressed	Average A1-A2 stressed only	Average B1 stressed and unstressed	Average B1 stressed only	Average B2 stressed and unstressed	Average B2 stressed only
[i] dominant (-ATR)	28 Pa**	20 Pa	29 Hz	26 Hz*	124 Hz	104 Hz
[i] recessive (+ATR)	21 Pa**	34 Pa	54 Hz	40 Hz*	148 Hz	136 Hz
Difference/ Significance	7 Pa** $t(8)=4.60$, $p=0.002$	14 Pa $t(3.13)=$ 2.27, $p=0.104$	25 Hz $t(6.62)=$ 2.11, $p=0.075$	14 Hz* $t(7.78)=$ 2.62, $p=0.031$	24 Hz $t(8)=1.14$, $p=0.286$	32 Hz $t(4.01)=$ 1.19, $p=0.298$
[a] (-ATR)	10 Pa	10 Pa	135 Hz	117 Hz	149 Hz	144 Hz
[æ] (+ATR)	13 Pa	13 Pa	116 Hz	80 Hz	203 Hz	238 Hz
Difference/ Significance	3 Pa $t(5.51)=$ 0.94, $p=0.387$	3 Pa $t(1.18)=$ 0.72, $p=0.586$	19 Hz $t(12)=0.63$, $p=0.544$	37 Hz $t(5)=1.09$, $p=0.325$	54 Hz $t(4.39)=$ 2.20, $p=0.087$	94 Hz $t(1.01)=$ 3.21, $p=0.174$
[o] (-ATR)	9 Pa***	9 Pa**	138 Hz	154 Hz	76 Hz	86 Hz
[u] (+ATR)	22 Pa***	22 Pa**	81 Hz	78 Hz	135 Hz	117 Hz
Difference/ Significance	13 Pa*** $t(7.91)=$ 6.01, $p<0.001$	13 Pa** $t(4.34)=$ 5.65, $p=0.004$	57 Hz $t(8)=1.81$, $p=0.108$	76 Hz $t(5)=1.57$, $p=0.337$	59 Hz $t(8)=2.26$, $p=0.053$	31 Hz $t(2.23)=$ 1.62, $p=0.233$

Table 15 Average values for intensity and bandwidth for FS2.

	Average A1-A2 stressed and unstressed	Average A1-A2 stressed only	Average B1 stressed and unstressed	Average B1 stressed only	Average B2 stressed and unstressed	Average B2 stressed only
[i] dominant (-ATR)	28 Pa	28 Pa	81 Hz*	81 Hz*	113 Hz	114 Hz
[i] recessive (+ATR)	27 Pa	27 Pa	46 Hz*	46 Hz*	128 Hz	122 Hz
Difference/Significance	1 Pa $t(4.13)=0.60$, $p=0.578$	1 Pa $t(4.47)=0.49$, $p=0.646$	35 Hz* $t(9)=3.08$, $p=0.013$	35 Hz* $t(8)=2.93$, $p=0.019$	15 Hz $t(9)=0.68$, $p=0.512$	8 Hz $t(8)=0.40$, $p=0.701$
[a] (-ATR)	13 Pa	13 Pa	130 Hz	119 Hz	164 Hz	165 Hz*
[æ] (+ATR)	15 Pa	15 Pa	127 Hz	103 Hz	142 Hz	112 Hz*
Difference/Significance	2 Pa $t(12)=0.65$, $p=0.531$	2 Pa $t(2.62)=0.61$, $p=0.593$	3 Hz $t(12)=0.14$, $p=0.891$	16 Hz $t(2.19)=0.45$, $p=0.691$	22 Hz $t(12)=1.08$, $p=0.304$	53 Hz* $t(5.53)=2.56$, $p=0.046$
[o] (-ATR)	13 Pa***	13 Pa	96 Hz	97 Hz	<i>87 Hz**</i>	<i>77 Hz*</i>
[u] (+ATR)	28 Pa***	28 Pa	72 Hz	78 Hz	<i>180 Hz**</i>	<i>177 Hz*</i>
Difference/Significance	15 Pa*** $t(3.88)=13.08$, $p<0.001$	15 Pa $t(1.21)=8.29$, $p=0.052$	24 Hz $t(4.82)=1.61$, $p=0.170$	19 Hz $t(1.14)=0.62$, $p=0.636$	<i>93 Hz**</i> $t(5.86)=4.58$, $p=0.004$	<i>100 Hz*</i> $t(3.14)=4.10$, $p=0.024$

Table 16 Average values for intensity and bandwidth for FS3.

	Average A1-A2 stressed and unstressed	Average A1-A2 stressed only	Average B1 stressed and unstressed	Average B1 stressed only	Average B2 stressed and unstressed	Average B2 stressed only
[i] dominant (-ATR)	16 Pa	16 Pa	90 Hz	90 Hz	127 Hz	127 Hz
[i] recessive (+ATR)	15 Pa	15 Pa	66 Hz	66 Hz	139 Hz	139 Hz
Difference/ Significance	1 Pa $t(7.83)=$ 1.46, $p=0.183$	1 Pa $t(8)=1.37$, $p=0.206$	34 Hz $t(7.91)=$ 0.88, $p=0.405$	34 Hz $t(7.9)=0.88$, $p=0.405$	12 Hz $t(7.98)=$ 0.63, $p=0.549$	12 Hz $t(7.9)=$ 0.63, $p=0.549$
[a] (-ATR)	6 Pa	6 Pa	93 Hz	101 Hz	140 Hz	167 Hz
[æ] (+ATR)	10 Pa	10 Pa	76 Hz	85 Hz	147 Hz	168 Hz
Difference/ Significance	4 Pa** $t(13)=$ 3.63 , $p=0.003$	4 Pa $t(6)=2.10$, $p=0.080$	17 Hz $t(13)=1.33$, $p=0.208$	16 Hz $t(2.56)=$ 1.18, $p=0.335$	7 Hz $t(13)=0.39$, $p=0.706$	1 Hz $t(6)=0.13$, $p=0.904$
[o] (-ATR)	8 Pa**	5 Pa**	89 Hz	115 Hz*	103 Hz	97 Hz
[u] (+ATR)	19 Pa**	19 Pa**	52 Hz	50 Hz*	130 Hz	133 Hz
Difference/ Significance	9 Pa** $t(4.87)=$ 5.28, $p=0.004$	14 Pa** $t(2.88)=$ 8.89 , $p=0.003$	37 Hz $t(4.58)=$ 2.00, $p=0.108$	65 Hz* $t(5)=3.48$, $p=0.018$	27 Hz $t(7.02)=$ 1.14, $p=0.294$	36 Hz $t(3.66)=$ 1.03, $p=0.366$